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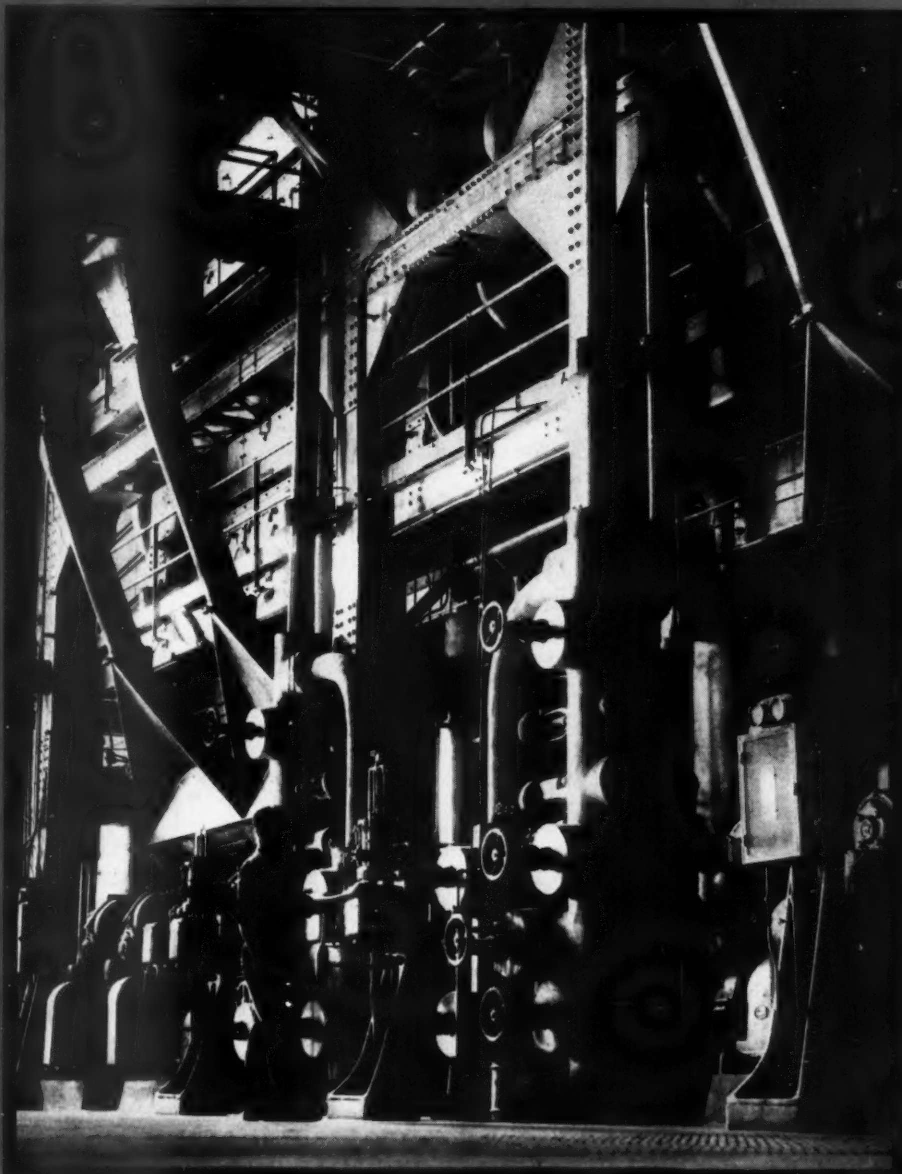

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Calculation of Air Requirements and Combustion Products of U. S. Coals by Simple Graphical Method

By W. S. PATTERSON

History and Developments in the Art of Welding Ferrous Metals

By A. J. MOSES

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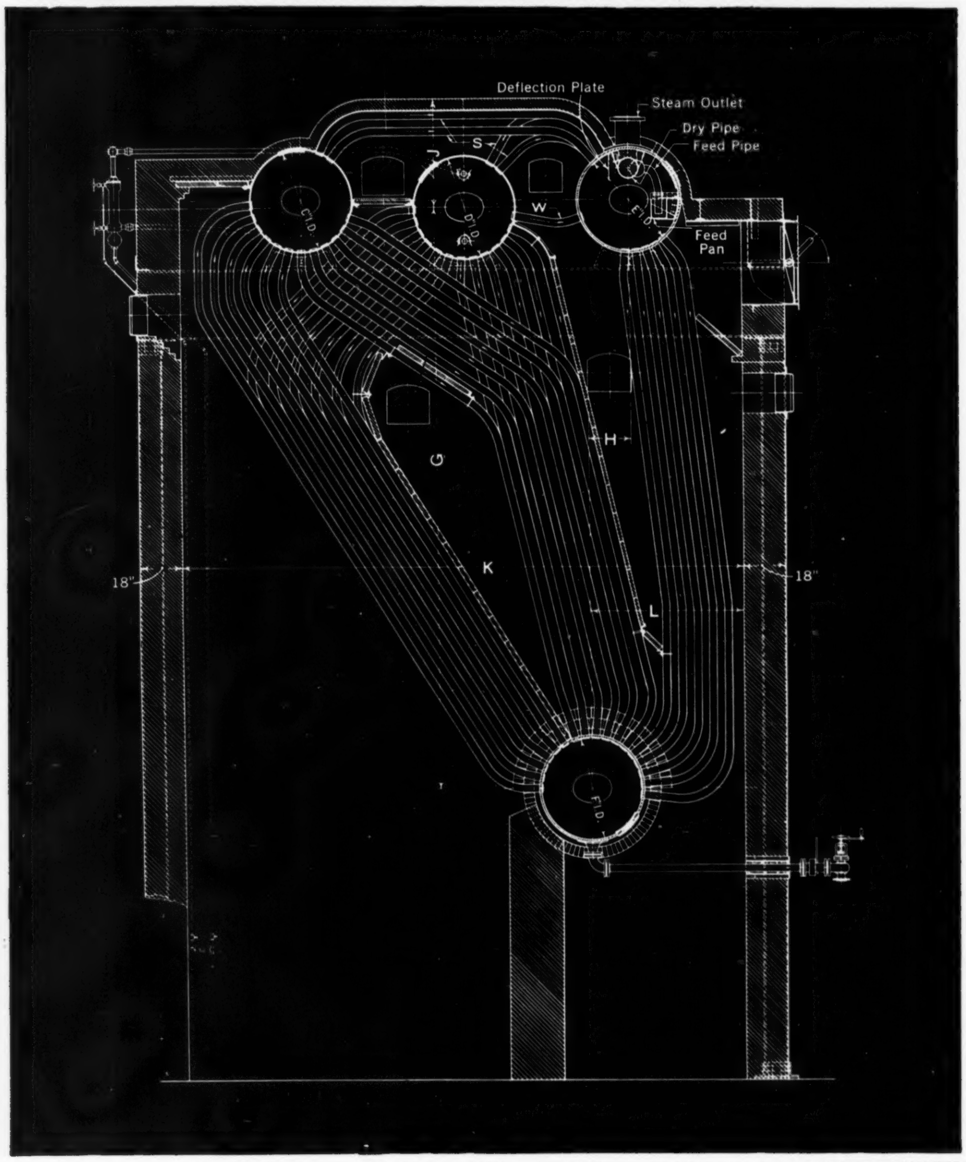
C-E MULTIPLE CIRCULATION BOILER



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COMBUSTION

VOLUME THREE • NUMBER EIGHT

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DEPARTMENTS

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EDITORIAL

This Question of Obsolescence

THINKING specifically in terms of the economics of steam plant equipment, the word obsolete may be correctly applied to any equipment that may be replaced with economies sufficient to justify such a step in the particular business concerned. Some distinction should be made with respect to type of business because of the varying ratio of steam and power costs to total production costs in different industries. For example a saving of 30 per cent in steam and power cost might represent an ultimate saving of only 1 per cent in certain lines where such costs are but a small part of the total production cost, and generally, in such industries, improvements in other departments may show greater returns. However, these cases are infrequent since opportunities for substantial savings in departments directly related to plant production have generally received first consideration. Similar or even greater opportunities in the steam plant have frequently been overlooked or have not commanded sufficient interest on the part of executives, unfamiliar with the technical problems involved, to be properly evaluated.

With the rapid progress that has taken place in the steam plant field in recent years, the problem of obsolescence has assumed greatly increased importance. The developments principally responsible for this progress are discussed in the article by G. W. Clendon and Otto de Lorenzi appearing in this issue. Even those familiar with the improvements in furnace design and firing methods will have an enhanced appreciation of this development after reading this article.

There can be no question that all this progress evolved directly from the first successful applications of pulverized fuel which made evident the necessity for new and better furnace linings if full advantage were to be taken of the potentialities of coal in pulverized form. This naturally led to the development, in the order mentioned, of the hearth or bottom screen, rear wall cooling, side wall cooling, and finally, the completely water cooled furnace. This, in turn, made practical the use of greatly increased rates of heat liberation and thus provided the incentive for the improved firing methods which followed.

Since the water cooled furnace proved to be as adaptable to stoker-fired as to pulverized-fuel-fired units and removed existing limitations to stoker performance, it thus joined hands with pulverized fuel in stimulating stoker manufacturers to improve their products.

As a result of this remarkable progress, conceptions of furnace design and heat liberation which represented good practice 7 or 8 years ago are obsolete today. A correctly designed modern furnace, as compared with the best practice of the early years of the last decade, permits greatly increased steaming capacity and assures higher efficiency, reduced maintenance and outage, and generally improved operation.

These advantages, if properly evaluated, will in many instances show economic justification for the revamping or replacement of existing units, even though such units may have been in operation for less than half their normal working life.

Such opportunities should be of particular interest at this time in plants where reduced operations make it possible to take one or more units off the line for revamping or replacement without overtaxing the remaining units. Procrastination in this matter will eventually impose penalties due to the greater hardship and cost of effecting these improvements under normal operating conditions.

The Utility Record for 1931

ADVOCATES of government ownership and operation of public utilities will find much food for thought in the record of our public utilities in 1931. During this period of economic stress the utilities have been a tower of strength in our industrial structure. Recently issued figures for the year reveal a situation that speaks volumes for the merits of private management.

For the first eleven months of 1931, and as compared with the same period of 1930, which represented the record year to date, the total kw. hr. generated showed a decrease of but 3.9 per cent, while the total revenue from consumers decreased but 1 per cent. The maintenance of revenue beyong the proportion indicated by these figures was due to an increase of 7.4 per cent in total domestic consumption, the field in which the higher rates prevail, and was effected despite a decrease of 3.5 per cent in the average revenue per kw. hr. in this field.

Significant of the tremendous size of the industry are the following figures issued as of November 30, 1931: Value of plant and equipment—$12,800,000,000; generating capacity—33,050,000 kw. Of the latter figure, 23,900,000 kw. is generated by steam. Further evidencing the increasing dependence upon steam-generated electricity is the fact that the reduction in kw.-hr. generated by fuel was but 1.8 per cent while the reduction in kw.-hr. generated by water power was 8 per cent. Continued improvement of efficiency in steam plants is shown by a reduction in the average pounds of coal per kw.-hr. from 1.59 lb. to 1.52 or 4.4 per cent.

A record such as this, achieved under the conditions of 1931, testifies conclusively to the inherent soundness and merit of private management.

Calculation of Air Requirements and Combustion Products of U. S. Coals by Simple Graphical Method

By W. S. PATTERSON

Combustion Engineering

Corporation, New York

In recent issues of COMBUSTION several articles have appeared on the subject of fuels and their combustion. Calculation of air requirements and products of combustion by the conventional methods, based on the chemical reactions involved, has been thoroughly discussed. The author of this article discusses the properties of coal which make it possible to calculate these air and gas weights by a simple graphical method, the accuracy of which he justifies in the introductory paragraphs. A single chart covering all coals except anthracite appears on Page 14. A similar chart for anthracite coal will be published in a later issue.

THE combustion of coal takes place as the result of exothermic chemical reactions between oxygen, the sole supporter of combustion, and the combustible constituents of the coal, namely, carbon, hydrogen, and sulphur. These reactions always take place in accordance with known and invariable weight relations which are characteristic of the properties of the elements involved, the results of which may be calculated in terms of quantity of heat evolved, oxygen required, and products of combustion produced from known quantities of the combustible elements present in the coal[1]. To calculate accurately the air requirements and products of combustion for perfect combustion of unit quantity of any coal therefore requires the accurate determination of the separate quantities of the combustible elements in the sample, which it is possible to do very accurately in a good fuel laboratory but only with considerable expense and consumption of time.[2] One might logically ask, therefore, whether the accuracy required in the calculation of air requirements and products of combustion in commercial practice justifies the time and money consumed in finding the chemical analysis of every coal sample encountered and in calculating the air requirements and products of combustion by the use of chemical equations or the use of the known weight relations mentioned above.[3] The answer to this question, in the opinion of the author, depends entirely on the accuracy with which it is possible to test the commercial equipment being considered and the accuracy with which it is possible to calculate air requirements and combustion products by some other method without resorting to the use of ultimate analyses and the involved calculations.

For instance, let us consider the case of equipment such as furnaces, boilers, superheaters, economizers, air heaters, etc., in which or under which coal is burned for the purpose of evolving and utilizing heat. The designer and manufacturer of such equipment desires to know the air and gas quantities to enable him to predict heat release, heat absorption, gas and air velocities, temperature, efficiency and resistance to flow throughout the apparatus. The purchaser or user of such equipment desires to measure these quantities to determine if the manufacturer's predictions were correct. But since an actual direct measurement of the gas and air quantities, as such, cannot be conveniently and accurately made these quantities are calculated indirectly from chemical analysis of the waste gases at different points throughout the apparatus. The accuracy of the analysis of a particular sample by the use of the Orsat apparatus is considered sufficient but the failure of the sample to truly represent the average composition of the combustion products passing through the apparatus at the point of sampling may introduce large errors, especially if sampling is not continuous and if only a few points of sampling are used in large passage areas. It is therefore impossible to directly or indirectly measure gas and air quantities as accurately as it is possible to determine the chemical analysis of the coal and thereby calculate theoretically these quantities. It is also impossible to measure heat transfer rate, true average temperature and draft loss, all of which are partly de-

NOTE: All references at end of article.

pendent upon the quantity of combustion products, with a degree of accuracy comparable to that of calculating these combustion products from the

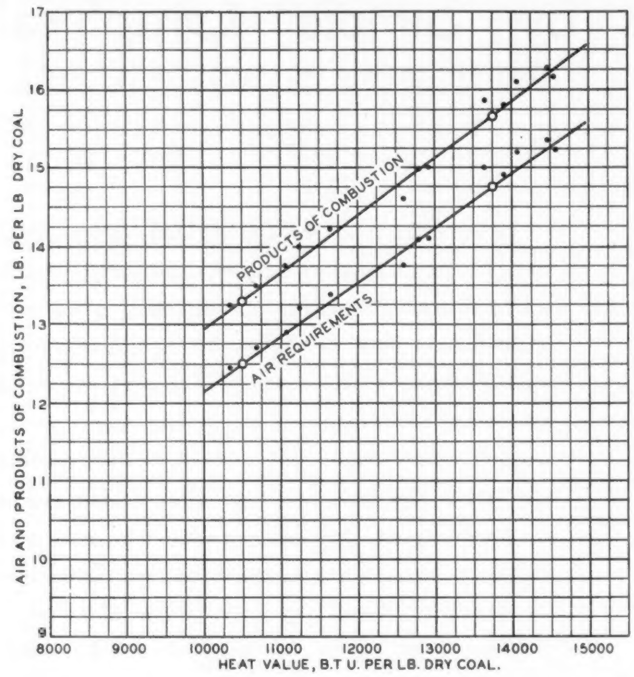

Fig. 1—Dry air required and true products of combustion for anthracite coal with 14 per cent CO_2 in combustion products.

chemical analysis of the coal, and a known quantity of air.

In view of the above the author therefore believes that the use of the shorter, simpler, and cheaper method of making these calculations as herein discussed and presented will give sufficient accuracy for the requirements of commercial practice. The results obtained from the author's chart will be within about three per cent (plus or minus) of the values as accurately calculated from the chemical analysis of the fuel. The use of the chart eliminates all the calculations necessary in the longer method since the gas and air weights per lb. of coal may be read directly with only a knowledge of the heat value of the coal required.

Basis of Graphical Method and Analysis of Available Data

The true products of combustion of "dry" coal with dry air consist of the dry products of combustion resulting from the combustion of the carbon and sulphur and the moisture resulting from the combustion of the hydrogen. Coal as fired, and atmospheric air with which it is burned, both always contain some moisture which is carried along with the true products of combustion but which generally is only a small percentage of the total gas produced. Therefore the total combustion products per pound of coal should be nearly directly proportional, within limits, to the weight percentage of combustible. And since the potential heat value of the coal is due to the possible chemical reactions between oxygen and the combustible constituents of the coal, it also bears a definite relation to and should be nearly directly proportional, within the same limits, to the weight percentage of combustible. It follows therefore, that the total combustion products per pound of coal should bear a definite relation to, and be nearly directly proportional to, the heat value of the coal.

This relation was used as the basis for the author's graphical calculation method and the limits mentioned above were allowed for by dividing all the coals of the U. S. into groupings according to volatile content since the volatile content is known to bear a relation to the hydrogen content[4] which in turn influences heat value and quantity of air and combustion products. And since certain coal names have become associated with coal age and volatile content it was found convenient to classify the coals studied according to the listing in Table I.

TABLE I—CLASSIFICATION OF COAL ACCORDING TO VOLATILE CONTENT

Coal Name	*Per Cent Volatile on Moisture Free Basis*
Anthracite	Under 7
Semi-anthracite	7 to 11
Semi-bituminous	13 to 22
Eastern bituminous	25 to 35
Western bituminous	35 to 45
Lignite	Over 45

The analyses of the many coals used for this study were made and published by the U. S. Bureau of Mines.[5] The number of analyses studied for the determination of the curves presented herein was about five hundred, covering all the ultimate analyses published for coals having heat value between 10,000 to 11,000 B.t.u. per lb., 13,000 to 14,000

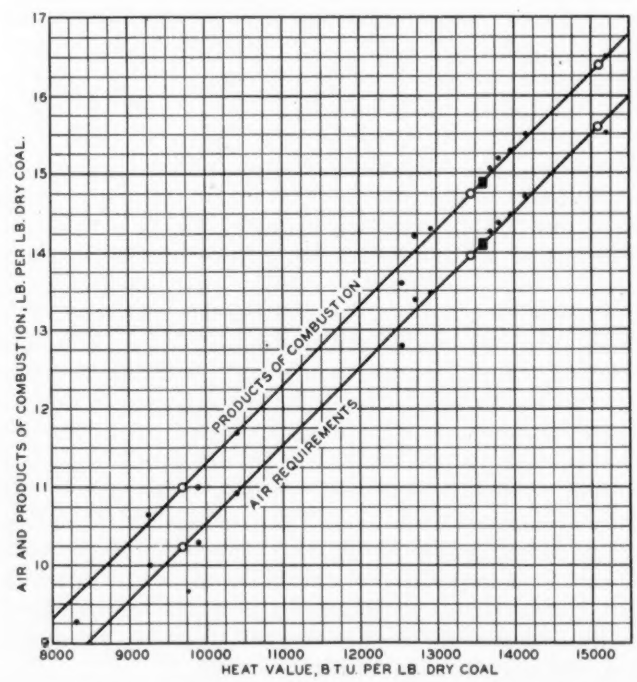

Fig. 2—Dry air required and true products of combustion for semi-anthracite coal of 7-11 per cent volatile, dry basis, with 14 per cent CO_2 in combustion products.

B.t.u. per lb., and all over 15,000 B.t.u. per lb. Selection and use of only the coals between these

ranges was sufficient to calculate three points and thus determine the shape of the curves. These analyses were then further grouped according to

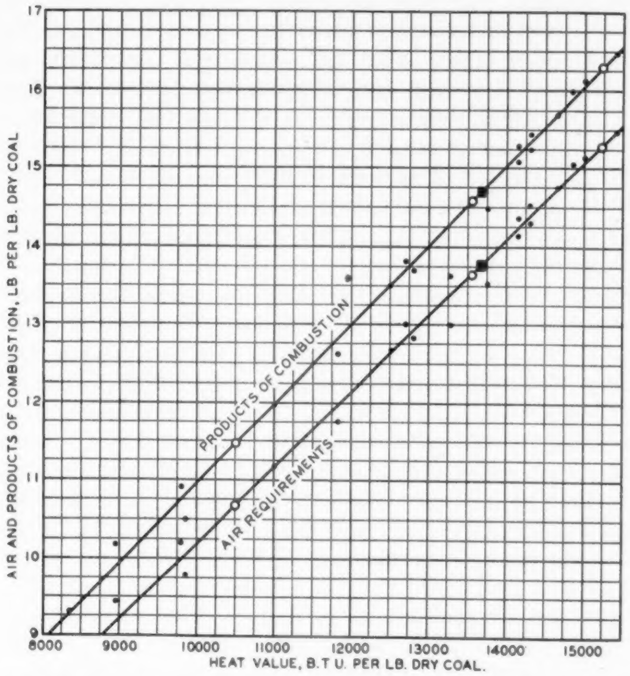

Fig. 3—Dry air required and true products of combustion for semi-bituminous coal of 13-22 per cent volatile, dry basis, with 14 per cent CO_2 in combustion products.

volatile content as outlined in Table I and an average analysis determined for each group. From each average analysis, air requirements and combustion products were then calculated by means of the well known relations between the fuel constituents and air supplied, which method was discussed in detail, in a recent issue of this magazine.[3] The results so calculated were based on complete combustion of all carbon in the coal and on sufficient dry air to produce in each case combustion products having a CO_2 content of 14 per cent by volume. All analyses used were "dry" or "moisture free" and the results used for plotting the curves in Figs. 1 to 5 inclusive are therefore the lb. of dry air required per lb. of dry coal and the resulting true products of combustion in lb. per lb. of dry coal, exclusive of the moisture contained in the fuel itself since this item can best be handled separately as will be explained later.

Analysis of Calculated Results

It was found that the air requirements and combustion products per lb. of dry coal so determined fall on straight lines when plotted against heat value per pound of dry coal, but that the gas and air quantities are not directly proportional to the heat value of the fuel. The curves for the range over which their shape was determined are of the form $y = mx + b$, where y = ordinate, lb. of gas or air per lb. of dry coal, x = abscissa, B.t.u. per lb. of dry coal, m = a constant, b = intercept on the ordinate scale, but the slope and apparent intercept value of each curve is different as will be noticed from Fig. 6. The method some engineers use of figuring a certain weight of gas or air per million B.t.u. fired as a good estimate of the requirements is thus shown to be subject to considerable error. It will be noticed, however, that the semi-anthracite and semi-bituminous coals have air requirements and products of combustion more nearly directly proportional to heat value than the high volatile coals.

A sufficient number of complete analyses of coals having more than 45 per cent volatile on a "moisture free" basis were not available to plot curves over the entire B.t.u. range used for Figs. 1 to 5 but it was found that the air requirements and combustion products of the average of ten coals between 10,000 and 11,000 B.t.u. per lb. and having 45 to 55 per cent volatile content, and the average of three coals averaging 63 per cent volatile content, were in exact agreement with the curves plotted on Fig. 5, which may therefore be taken to include all coals having over 35 per cent volatile content.

A further check on the curves plotted in Figs. 1 to 5 was made by selecting at random coals of different volatile content and heat value from different States of the U. S. and by plotting their air requirements and combustion products as calculated from Bureau of Mines analyses on the various

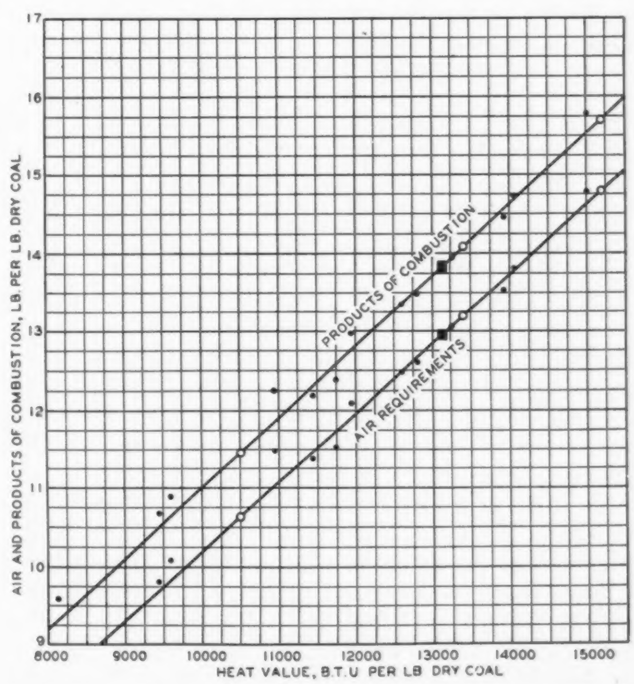

Fig. 4—Dry air required and true products of combustion for eastern bituminous coal, 25-35 per cent volatile, dry basis, with 14 per cent CO_2 in combustion products.

curves of Figs. 1 to 5. The points indicated by the small solid circles correspond to the check points used.

Also it was found that in many of the groupings, certain coals were peculiar and very different from the average analysis of the group. These were used to determine whether their peculiar differences would affect the curves to any extent. They

consisted of such groups as: 14 coals averaging 40 per cent volatile but with extremely low ash content; 8 coals averaging 40 per cent volatile but with unusually high sulphur and hydrogen content; 13 coals averaging 15 per cent volatile but with ex-

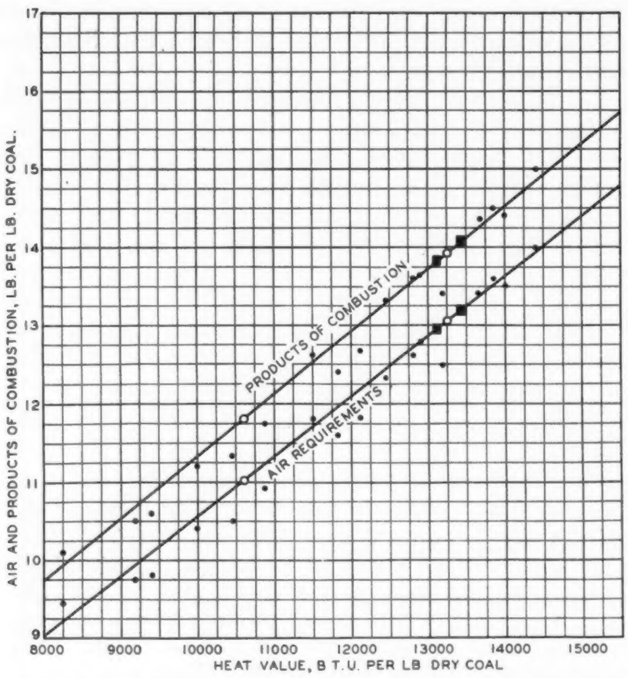

Fig. 5—Dry air required and true products of combustion for western bituminous coal, 35-45 per cent volatile, dry basis, with 14 per cent CO_2 in combustion products.

tremely low hydrogen and sulphur content; and 15 coals averaging 30 per cent volatile but with high ash content. The air and gas weights for these groups are represented by the points shown as solid squares on Figs. 3, 4 and 5.

Fig. 6 shows the "products of combustion" lines from Figs. 1 to 5 inclusive plotted together for comparison. It will be noted that, with the exception of anthracite, the error of using an average curve for all coals of the U. S. including lignite is small, being only about plus or minus three per cent based on the average curve as shown in this Figure. Moreover, the error is greatest at the extreme high and low ends of the B.t.u. scale for the extremely high and low volatile coals, which represent extreme conditions seldom to be encountered in large scale commercial practice in this country, with perhaps the exception of lignite. The "average" line as plotted on Fig. 6 was therefore used as the key for the working chart, Fig. 7, which may be used for all coals of over 7 per cent volatile content, "moisture free" basis.

Calculation of Gas Weights from Fig. 7 Chart

The total weight of gas resulting from the commercial burning of one pound of coal with atmospheric air consists of (1) the dry products of combustion including the excess oxygen and nitrogen in the excess air, (2) the moisture resulting from the combustion of the hydrogen in the coal, (3) the moisture of the coal itself as fired, and (4) the moisture due to humidity of the air used for combustion. The total wet gas weight per pound of coal therefore depends on the weight of moisture in the fuel as actually fired but may be expressed as pounds per pound of dry coal by dividing by (1-weight fraction of moisture) in which case the heat value may also be expressed as B.t.u. per pound of dry coal by dividing the "as fired" heat value by this same fraction. Thus the expression "wet gas per pound of dry coal" is really the wet gas per pound of wet coal expressed in terms of the dry fraction of coal taken as unity. It is comparable to expressing the number of apples in a basket of apples and oranges as so many apples per orange in the basket. Coal "as received" at a plant may contain a different amount of moisture than "as received" at the laboratory for analysis and both may vary with weather conditions. Also in a plant burning pulverized fuel the coal may carry one percentage of moisture as delivered to the raw coal bunker, another as delivered to the pulverizer, another as delivered to the pulverized fuel bunker, and still another "as fired." Furthermore when a laboratory determines an "ultimate" or chemical analysis as "wet," "as received" or "as fired," the moisture is reported as hydrogen and oxygen and added to the hydrogen and oxygen of the coal itself. Obviously therefore many engineers prefer to work with the analysis, heat value, air weight, and gas weight expressed per pound of dry coal. This method was used by the writer in plotting the Fig. 7 chart.

The "average" line from Fig. 6 gives only the sum of combustion products (1) and (2) as numbered in the preceding paragraph and is based on complete combustion of all carbon. An accurate calculation must however include products (3) and (4) and make allowance for assumed or measured unburned carbon. It is possible to burn coal commercially with complete combustion of all carbon *burned* but it is impossible to burn all the carbon. An analysis of the refuse must be made to determine the unburned carbon, the weight of which per pound of coal may be calculated from the following formula for each portion of the total refuse from which a sample is taken:

$$C_L = \left[\frac{C_R \times KA}{(1 - C_R)}\right]$$

where C_L is the weight of carbon in the refuse per pound of dry coal fired, C_R is the weight of carbon per pound of dry refuse, A is the weight of ash per pound of dry coal, and K is a constant representing the known or assumed fraction of the total ash deposited in the refuse sampled. Thus if different parts of the total refuse, such as ashes, clinkers, soot hopper dust and flue dust contain different percentages of unburned carbon the fraction K of the total ash, A, in each must be estimated such that their sum equals unity, and the sum of the several C_L values so calculated is the total weight of unburned carbon per pound of dry coal. For example in a pulverized fuel boiler installation the

K fraction for the ash pit might be .20 and that for the stack .80 while the C_R values might be .02 and .20 respectively; in which case the ash pit loss could be neglected, and, based on 10 per cent ash in coal, the total unburned carbon would be $(.20 \times .80 \times .10) \div (1 - .20) = .02$ lb. per lb. of dry coal, or 2 per cent. The carbon loss correction scale shown along the left side of Fig. 7 provides correction for from 0 to 5 per cent as calculated above. No correction has to be made however for exactly two per cent unburned carbon because the chart has been plotted so as to automatically take care of this amount.

The combustion products as read direct from Fig. 7 include the moisture in atmospheric air supplied, based on 50 per cent relative humidity at 70 deg. fahr., but do not include the moisture from the coal for the reason that this quantity is subject to such a variation as explained above. The determined or assumed quantity of moisture expressed as pounds per pound of dry coal may simply be added to the reading from the chart.

The Fig. 7 chart is plotted for variable excess air expressed in terms of CO_2 content in the gases because it has become the custom to think more in terms of per cent CO_2 when working with coal than in terms of per cent excess air, both in connection with test and design calculations.

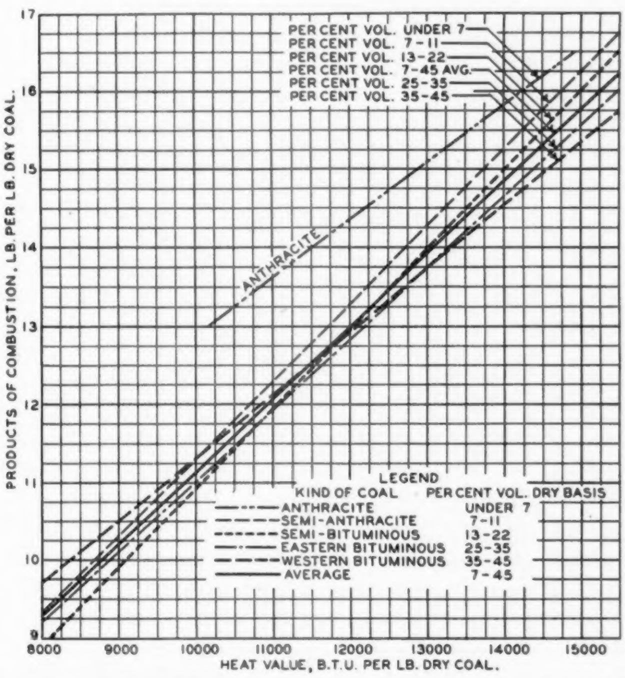

Fig. 6—True products of combustion of all U. S. coals, including anthracite, plotted for comparison, from Figs. 1 to 5.

To calculate from the chart the total wet gas resulting from the combustion of any coal other than anthracite, it is therefore necessary to know only the heat value, moisture content, and measured or calculated CO_2 and carbon loss.

Calculation of Air Weights from Fig. 7 Chart

The proximate analysis of a coal is reported as moisture, fixed carbon, volatile, and ash. The proximate analysis, dry basis, would therefore include only fixed carbon, volatile and ash of which the volatile and fixed carbon are sometimes added together and called "combustible." Considering the dry coal as consisting of combustible and ash, the "true" products of combustion of one pound of dry coal equals the weight of this combustible burned per pound of dry coal plus the weight of dry air supplied. Therefore the dry air weight required per pound of dry coal equals the true products of combustion per pound of dry coal minus unity plus the weight of ash per pound of dry coal plus the weight of unburned carbon per pound of coal, which may be written:

Dry Air = (True Products—Combustible Burned) = True Products — (1 — Ash — Carbon Loss). Now if we add to the "true" products, the moisture due to humidity of the air this sum is the gas quantity read direct from Fig. 7 chart, and we may write:

Atmospheric Air = (True Products + Moisture from Air) — (1 — Ash — Carbon Loss). The principle of this indirect method of determining the air weight has been applied to the Fig. 7 chart by using Curve A of the chart to determine the quantity to be subtracted from the gas weight read from the chart.

As stated previously in this article the heat value of coal bears a definite relation to and should be nearly directly proportional to the weight percentage of combustible. This refers to the combustible elements hydrogen, carbon and sulphur but the same statement may be made, with less accuracy, about the relation between the heat value and the term "combustible" meaning everything but the ash in a dry analysis. Fig. 8 shows this relation plotted from the numerous analyses studied. It will be noted that for the same heat value the percentage of ash decreases as the percentage of volatile increases, the variation being greater with low heat value fuels. A line representing the average combustible and ash content for all coals in the U. S. is drawn midway between the limit lines and is replotted as Curve A on Fig. 7 chart.

The error introduced by using the average ash content values thus determined is negligible even with coal of low heat value as will be seen from a numerical example. For instance, consider a coal having 12,000 B.t.u. per lb. dry coal to be burned with 2 per cent carbon loss to produce gases having 14 per cent CO_2. The wet gas resulting, not including moisture from the coal itself, is 12.70 lb. per lb. dry coal as read direct from Fig. 7. The ash from the average curve of Fig. 8 is .15 lb. so that the weight of air per lb. dry coal becomes $12.70 - (1 - .15 - .02) = 11.87$. Now if the ash content were actually known it would probably be not greater than .21 and not less than .09 as indicated by the limit lines of Fig. 8. Either value would put the average value in error by .06 lb. which is .06 lb. in 11.87 lb. or about one-half of one per cent error in air weight. The error introduced by neglecting the carbon loss in this part of the calculation is generally also negligible. If used in con-

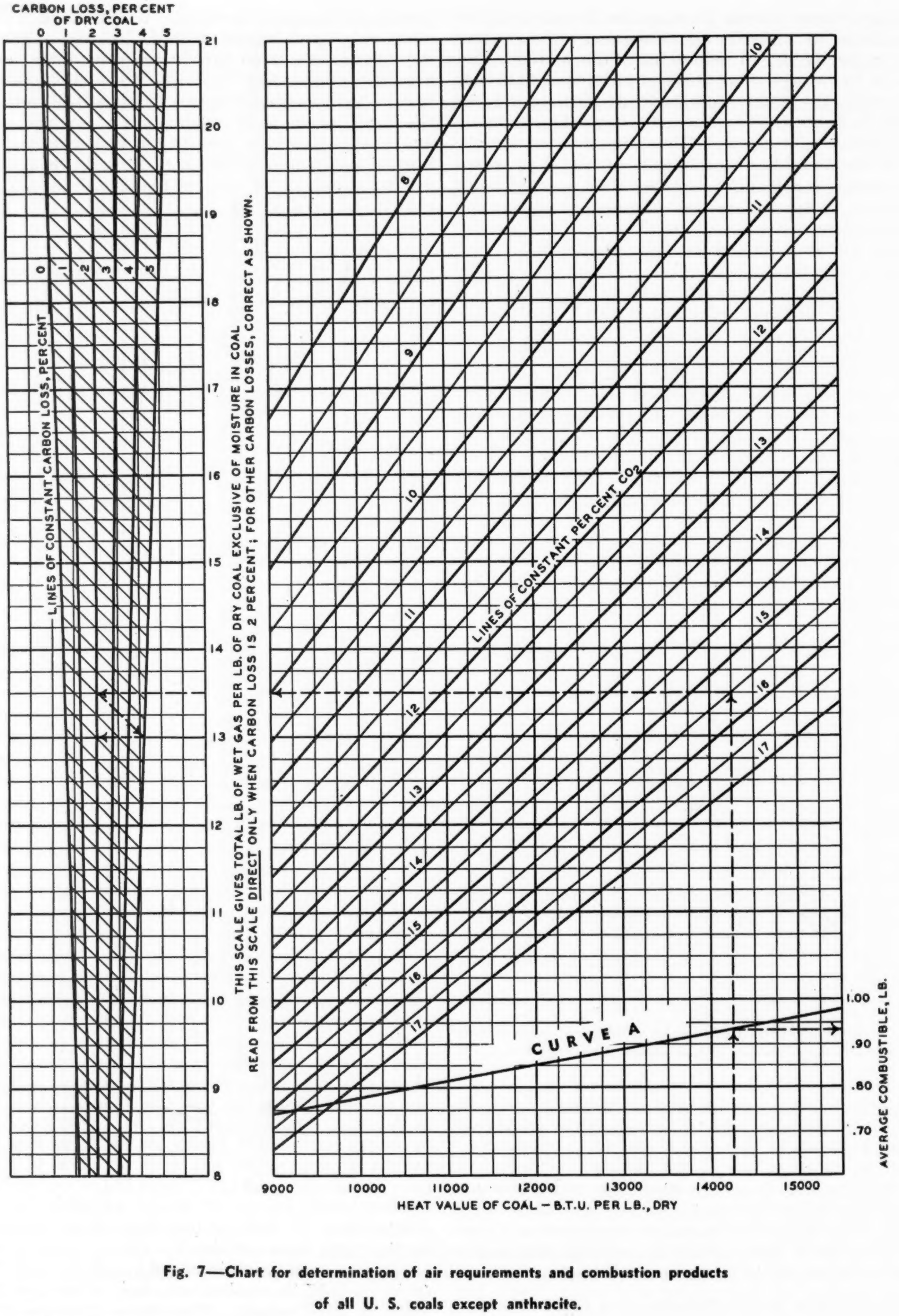

Fig. 7—Chart for determination of air requirements and combustion products of all U. S. coals except anthracite.

nection with power plant equipment extreme accuracy in the air weight calculation is not warranted for the reason that it is not used for any purpose requiring great accuracy. The air weight per pound of coal calculated for instance from a CO_2 analysis obtained at the outlet of a boiler includes all the air that actually was supplied under control for combustion plus the uncontrolled leakage into the furnace and boiler settings. Since this uncontrolled leakage may vary from 10 to 50 per cent of the total air supplied it is practically impossible to predict within 5 per cent the percentage of the total air that will be under control.

Advantages and Disadvantages of the Graphical Method

The greatest advantage of the graphical method described herein, as compared with the conventional calculation methods, is the saving in time and expense, without much sacrifice in accuracy. The graphical method requires knowledge only of the heat value and moisture content of the fuel; other methods are based upon the ultimate analysis of the fuel. The cost of obtaining heat value and moisture determination from a fuel laboratory is about $8.00; the cost of a complete ultimate analysis is about $25.00. The cost of a proximate analysis is about $15.00, from which the ultimate analysis may be determined in two ways, first, by calculation, or second, by locating a similar proximate analysis among published analyses, such as Bureau of Mines Bulletin 22, and using the corresponding ultimate analysis. Either of these requires considerable time. Then, with the ultimate analysis known, the conventional calculation methods[3] require further calculations, which, if made for a set of conditions involving variable excess air and variable carbon loss, would require several hours of time even by one quite familiar with the work. The graphical method requires only a few minutes for the same determination.

Another advantage of the graphical method is that it permits the quick and accurate calculation of the *effect* of such variables as heat value, excess air, and carbon loss on the final result, even though there may be some considerable known error in the actual figure arrived at.

The principle used by the author to cover all coals in the U. S. except anthracite and embodied in the Fig. 7 chart may be applied with greater accuracy to a more limited group of coals. For instance, a certain large public utility buys coal of a certain general type continually from a certain mining locality. It has available in its laboratory files numerous records of ultimate analyses taken perhaps over a period of several years. From these, by the method outlined in this article, very accurate charts similar to Figs. 6, 7, 8 and 9 may be constructed which will give gas and air weights with an error of less than one per cent. It is partly for this reason that the method of constructing the different curves has been explained in detail; engineers interested in the subject can construct more accurate charts in this manner, and thereafter analyze their coal only for heat value and moisture to calculate heat balances.

This brings us to the point of discussing the errors involved in using the Fig. 7 chart as plotted for such a broad group of coals. As was mentioned in connection with Fig. 6, the maximum error between the average line drawn and the actual lines reproduced from Figs. 1 to 5, is plus or minus three per cent. This is not however the

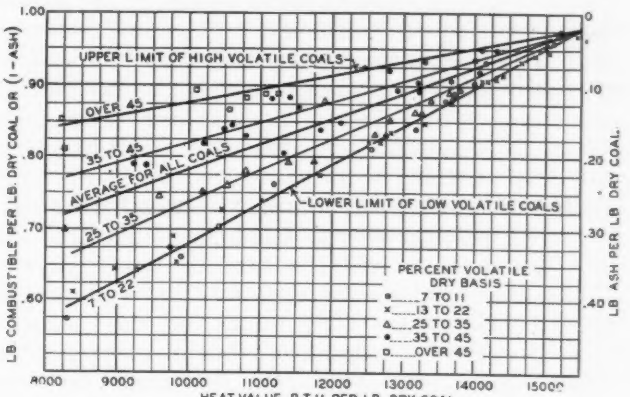

Fig. 8—Relation between ash content and heat value of all U. S. coals except anthracite.

maximum error possible since all the points used for determination of the lines on Figs. 1 to 5 do not fall exactly on the lines drawn. It is obvious therefore that in some cases the error may be greater or less depending in general on the volatile content and in particular on some peculiarity which the coal may have. Use of the incorrect heat value also introduces an error since this is one of the coordinates used for plotting all the curves. However during the three years that the Fig. 7 chart has been in use by the author and his associates it has proved itself to be very accurate and a valuable time saver.

In connection with a heat balance calculation it is necessary to segregate the moisture in the flue gas resulting from the combustion of hydrogen. The fact that the Fig. 7 chart does not segregate this quantity would be an objectionable feature were it not possible to determine the hydrogen content of the fuel quite accurately from the heat value and approximate volatile content. This relation is shown by Fig. 9 which is plotted from numerous analyses from U. S. Bureau of Mines Bulletin 22 including those used for determination of the other curves published herewith. By means of Fig. 9 it is therefore possible to determine the weight of moisture from combustion of hydrogen which makes it possible to calculate the heat balance without the use of a complete ultimate analysis.

Numerical Examples of Use of Fig. 7 Chart

To illustrate the simplicity and accuracy of the Fig. 7 chart, several examples will be worked out using the typical coals listed by the author of an article appearing several months ago in this magazine[3]. The results of the accurate air and gas weight determinations for these coals, based on

the ultimate analysis, are given in curve form in that article. These will be compared with the results obtained from the Fig. 7 chart. All calculated results are tabulated in Table II and will be referred to by the Item number.

The coals for which Fig. 7 may be used include all coals except anthracite, such as: S-10, Pocahontas and New River semi-bituminous; S-11, Pittsburgh bed eastern bituminous; S-12, Illinois high grade western bituminous; S-13, Illinois and Iowa low grade western bituminous; S-14, Wyoming western sub-bituminous; and, S-15, Texas lignite. The heat value and moisture content of typical coals of these types appear as Items (2) and (3) respectively which are on the "as fired" basis. For use in connection with the Fig. 7 chart these may be converted to "moisture free" basis by dividing by the decimal-fraction (1—moisture). The results of this conversion appear as Items (4) and (5). Calculations will be made for 14 per cent CO_2 in the products of combustion, and no unburned carbon loss since no carbon loss was allowed for in the calculations[3] with which these results are to be compared. Locating the heat value, Item (4), on the abscissa scale of Fig. 7 and proceeding vertically upward to the 14 per cent CO_2 line and thence to the left horizontally to the ordinate scale, the value read from this scale is the pounds of gas per pound of dry coal for 2 per cent carbon loss, exclusive of the moisture in the fuel. Since our calculations are to be based on no unburned carbon loss we proceed to the left to the 2 per cent carbon loss line and then correct for zero carbon loss by moving diagonally upward, along or parallel to the 45 deg. guide lines, to the zero carbon loss line. Reading the result again from the left hand ordinate scale we obtain Item (6) the pounds of gas per pound of dry coal, exclusive of moisture in the coal, corresponding to zero carbon loss and 14 per cent CO_2. Adding Items (5) and (6) we obtain the total wet products of combustion per pound of dry coal, Item (7). Now in order to find the error in our results by comparing them with the values calculated from the ultimate analysis[3] we may convert them to the "as fired" basis by multiplying by the decimal-fraction [1—Moisture, Item (3)] which gives Item (8). Item (9) lists the correct total wet products from which Item (8) has been subtracted to determine the error, which is expressed in per cent of the correct value, Item (10).

The weight of atmospheric air per lb. of dry coal Item (12) is determined by locating the heat value,

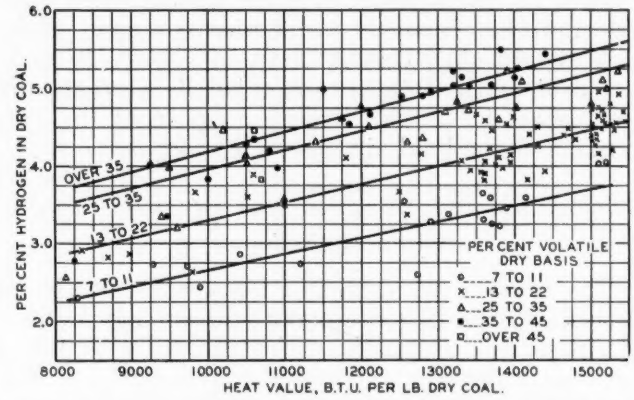

Fig. 9—Relation between hydrogen content and heat value of all U. S. coals except anthracite.

Item (4) on the abscissa scale of Fig. 7 and proceeding vertically upward to Curve A and thence to the right horizontally reading from the right hand ordinate scale the quantity, Item (11), to be subtracted from the gas weight, Item (6), previously read from the left hand ordinate scale. Although this is a direct subtraction from the gas weight the resulting air weight will not be in error by the same amount as the gas weight unless the value read from the Curve A agrees exactly with the weight of combustible burned per pound of dry coal, which, for the example being worked, equals (1—ash content) since no unburned carbon loss is being considered. Item (12) has been converted to the "as fired" basis in Item (13) for comparison with Item (14), the correct atmospheric air weight calculated from the ultimate analysis. The difference between Items (14) and (13) expressed as per cent of the correct value is the error given in Item (15).

The above calculations have been made with only a knowledge of the heat value and moisture

TABLE II—COMBUSTION CALCULATIONS FOR TYPICAL COALS OF VARIOUS TYPES

Item No.							
(1)[3]	Coal Reference Number	S-10	S-11	S-12	S-13	S-14	S-15
(2)[3]	Heat value, B.t.u. per lb., as fired	14300	13500	11800	10200	8500	7000
(3)[3]	Moisture, lb. per lb. coal, as fired	.028	.034	.100	.139	.224	.347
(4)	Heat value, B.t.u. per lb., moisture free	14720	13975	13115	11850	10950	10725
(5)	Moisture, lb. per lb. coal, moisture free	.0288	.0352	.1112	.1614	.2890	.5315
(6)	Lb. gas, 14 per cent CO_2, no C loss, from Fig. 7	15.65	14.95	14.10	12.90	12.00	11.80
(7)	Total lb. wet gas per lb. dry coal	15.68	14.99	14.21	13.06	12.29	12.33
(8)	Total lb. wet gas per lb. coal, as fired	15.25	14.48	12.80	11.25	9.53	8.05
(9)[3]	Total wet gas calculated from ultimate analysis	15.50	14.30	12.50	11.10	9.50	7.95
(10)	Error in gas wt. calc. from Fig. 7 Chart, per cent	—1.61	+1.26	+2.40	+1.35	+.32	+1.26
(6)	Lb. gas, 14 per cent CO_2, no C loss, from Fig. 7	15.65	14.95	14.10	12.90	12.00	11.80
(11)	(1-Ash) values from Curve A, Fig. 7	.95	.92	.89	.84	.81	.80
(12)	Atmospheric air, lb. per lb. dry coal, Fig. 7	14.70	14.03	13.21	12.06	11.19	11.00
(13)	Atmospheric air, lb. per lb. coal as fired	14.29	13.56	11.90	10.38	8.68	7.18
(14)[3]	Atmospheric air calc. from ultimate analysis	14.50	13.40	11.50	10.20	8.50	6.90
(15)	Error in air wt. calc. from Fig. 7 Chart, per cent	—1.45	+1.20	+3.50	+1.76	+2.1	+1.85
(16)[3]	Hydrogen, lb. per lb. dry coal by analysis	.0456	.0487	.0511	.0465	.0452	.0459
(17)	Hydrogen, lb. per lb. dry coal, from Fig. 9	.0440	.0495	.0500	.0465	.0445	.0435

content required so far as the coal is concerned, and the errors listed as Items (10) and (15) are not excessive. It is logical to assume however that one would also know the kind of coal, that is whether semi-anthracite, semi-bituminous, bituminous or lignite, etc. With this knowledge, it is possible to increase the accuracy of the above calculations if greater accuracy is warranted. Referring to Fig. 6, it will be noted that by using the "average" curve one would expect a plus error in some coals and a minus error in others depending on the heat value and kind of coal. For instance coal S-10 is a semi-bituminous coal of 14,720 B.t.u. per lb., moisture-free, for which Fig. 6 indicates that the "average" curve, which is the basis for Fig. 7 chart, will give a gas weight which is .20 lb. too low. Correcting for this in Item (7) and changing to the "as fired" basis we have $(15.68 + .20) \times (1 - .028) = 15.43$ which is in error by only $.07/15.50 = .45$ per cent with the correct value, Item (9). This reduction in error in the gas weight automatically reduces the error in the air weight since the air weight is obtained by subtraction of (1—Ash) from the gas weight.

An illustration of the use of Fig. 9 has been given by listing as Item (17) the percentage of hydrogen per lb. of dry coal obtained from the curves for the various coals. By comparing these values with Item (16), the hydrogen percentage by analysis, it will be noticed that the error is not excessive. Hydrogen percentages obtained from Fig. 9 can therefore be used to calculate the weight of moisture from this source with sufficient accuracy for ordinary heat balance calculations.

[1] Combustion Heat Balance, Wm. L. DeBaufre in COMBUSTION, June, 1931.
[2] Composition and Heating Value of Fuels, Wm. L. DeBaufre in COMBUSTION, May, 1931.
[3] Typical Solid and Liquid Fuels, Wm. L. DeBaufre in COMBUSTION, August, 1931.
[4] U. S. Bureau of Mines Technical Paper 197 and COMBUSTION for May, 1931.
[5] U. S. Bureau of Mines, Bulletin 22, Part 1.

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Hagan Corporation, Hall Laboratories, Inc., and the Swann Corporation have formed a new company known as the Buromin Company, with headquarters at 309 Bowman Bldg., Pittsburgh, Pa. This new company it is stated was formed in order to make available to small plants the Hall system of boiler water conditioning. The Hall Laboratories, Inc. has given the Buromin Company the rights to practice in the small plants of this country the patented Hall method of boiler water conditioning, and also will act as consultants for the new company. The company has secured from Hagan Corporation the right to sell Hagan Phosphate as Buromin. It has an agreement with the Swann Corporation for the manufacture of Hagan Phosphate in liquid form.

The Allied Research Laboratories of Glendale, Calif., announce the discovery of a solder that will repair cast iron pipe. This solder is called Alumaweld and it is claimed for it that it will repair any metal, including cast iron, steel, aluminum, pot metal, die castings, brass, bronze, etc. The sponsors advise that,

"Tests in which Alumaweld has repaired pipe systems indicate the extreme simplicity of this new solder. The broken part is cleaned and then heated with an ordinary soldering iron. Then the solder, with special flux, is applied, and the repair completed. Average pipe repairs take from 10 to 12 minutes and are made without tearing down the system.

Alumaweld, as the name implies, is more than a surface solder. It actually breaks down the structure of the metal to which it is applied and fuses or welds with it to form a single, solid piece. It is ten times as hard as ordinary solder, machines easily, is quite ductile, and will take a nice polish over which chromium plating or any other plating can be applied. It will not corrode under ordinary circumstances and cannot possibly rust, due to the fact that there is no electrolitic action between the metal and the solder. Alumaweld will withstand pressure up to 1000 lb. hydrostatic or cold water pressure, and will hold up to 500 lb. steam pressure at live steam temperature."

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Westinghouse Electric & Manufacturing Company announces the following appointments: John E. Barkle as general manager of their South Philadelphia Works. Mr. Barkle was formerly works manager at South Philadelhpia, having entered the employ of the company in 1901. Previous to being works manager he was superintendent of all generating apparatus at East Pittsburgh. D. W. Dean was appointed manager of the Control Section of the Industrial Department, East Pittsburgh, Pa. He succeeds the late W. H. MacGillivray. Mr. Dean has been connected with Westinghouse since 1921 and prior to that was in the electrical department of the Buckeye Steel Castings.

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Link-Belt Company, Chicago, Illinois, announce that the George W. Moore Company, Chicago, has been merged with H. W. Caldwell & Son Company, a Link-Belt subsidiary.

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The Air Preheater Corporation, manufacturers of the Ljungstrom regenerative air preheater, Wellsville, N. Y., announce the appointment of Mr. Irving M. Day, 306 Chandler Building, Washington, D. C., as representative in the Washington District.

The SO_4-CO_3 Ratio for the Prevention of Sulphate Boiler Scale*

The investigation described in this paper is a logical development of R. E. Hall's well-known work. The authors felt that the true value of the SO_4-CO_3 ratio must be appreciably greater than the value calculated by Hall, and, as a result, a program of research at the University of Michigan was sponsored by The Detroit Edison Company to determine more accurately, if possible, the solubility relations of boiler waters. The work done on this project is described by the authors.

By

EVERETT P. PARTRIDGE[1]

W. C. SCHROEDER[2]

and R. C. ADAMS, Jr.[3]

WHEN R. E. Hall applied physical chemistry to the control of boiler-water conditions he rendered an inestimable service to boiler operators. His work described in his well-known bulletin[4] and in numerous publications has stimulated many other investigations. The one described in the present paper is a logical development from Hall's pioneering efforts. While the authors believe that the present paper modifies the numerical value of Hall's SO_4–CO_3 ratio to an important degree, they feel that their investigations in no way detract from the brilliance of Hall's earlier efforts.

It seemed probable to the authors that the true value of the SO_4–CO_3 ratio must be appreciably greater than the value calculated by Hall. As a result a program of research at the University of Michigan was sponsored by the Detroit Edison Company in order to determine more accurately, if possible, the solubility relations in boiler waters. The research on this project was carried on continuously from February, 1929, to July, 1931.

Methods of Deriving the SO_4-CO_3 Ratio

Only a brief comparison of Hall's derivation of his SO_4–CO_3 ratio and of the present authors' method of evaluating this ratio will be given in this paper, since the subject has been discussed in a more complete form in a paper presented before the American Chemical Society which is to be published soon. The purpose of the present paper is to place the results before boiler operators for discussion.

Hall's Derivation. Hall evaluated the SO_4–CO_3 ratio for the simultaneous existence of solid anhydrite ($CaSO_4$) and solid calcite ($CaCO_3$) in equilibrium with a boiler water at a given temperature by using the concept of the solubility product. His method of derivation is open to three criticisms. The first of these is that a boiler steaming at a high rating may not actually approach an equilibrium condition, but instead the boiler water may be more or less supersaturated with respect to either anhydrite or calcite or both substances. The second criticism is that Hall made a long extrapolation of Kendall's uncertain data for the solubility of calcite in the range up to 100 deg. cent. in order to obtain the solubility product for calcite at boiler temperatures. The third point is that Hall's use of the ionization data of Noyes involves considerable uncertainty, since it leads to rather large variations in the value of the solubility product, which theoretically should be a constant. Hall himself noted these variations,[5] but since the fluctuations for both anhydrite and calcite were in the same direction, he assumed that they would largely cancel out in the ratio.

A New Method of Evaluating Hall's Ratio. Most boiler waters fall in the range of dilute solutions, as usually defined by the physical chemist. It seemed, therefore, that it might be profitable to apply some of the newer developments in the field of dilute solutions to the study of boiler-water equilibria. Some years ago Lewis and Randall[6] had discussed their development of the activity concept with relation to dilute solutions, and Debye and Huckel sub-

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* Contributed by the Joint Research Committee on Boiler Feedwater Studies. Presented at the Annual Meeting, New York, N. Y., Nov. 30 to Dec. 4, 1931, of The American Society of Mechanical Engineers.

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[2] Fellow in Boiler Feedwater Studies, Department of Chemical Engineering, University of Michigan, and Detroit Edison Fellow in the study of boiler-scale formation.

[3] Chemical Engineer engaged in boiler-water studies, U. S. Naval Experiment Station.

[4] R. E. Hall, et al., Carnegie Institute of Technology, Mining and Metallurgical Investigations, Bulletin 24, 239 pp., 1927.

[5] R. E. Hall, *Ind. and Eng. Chem.*, vol. 17, pp. 283-290, 1925.

[6] Lewis and Randall, "Thermodynamics and the Free Energy of Chemical Substances," McGraw-Hill Book Co., New York, 1923, pp. 326-385.

sequently supplied a highly mathematical theoretical substantiation of the empirical conclusions reached by Lewis and Randall. It is interesting to note that the Debye-Huckel theory has recently been applied to the field of boiler-water chemistry by McKinney.[7]

The present authors started from Lewis and Randall's definition of the "ionic strength" as a measure of the total concentration of a dilute solution and of the "mean molality" as a measure of the solubility of a saturating substance in such a solution. The ionic strength, represented by the symbol μ, is defined by the equation,

$$\mu = \frac{['] + 4[''] + 9['''] + \ldots.}{2}$$

where the brackets represent the respective sums of the concentrations of all the uni-valent, bi-valent, and tri-valent ions present in the solution under consideration. Concentrations are customarily expressed in mols per 1000 grams of solution and are stoichiometric values involving no theoretical considerations of ionization. The mean molality for a substance such as $CaSO_4$ or $CaCO_3$ is the square root of the product $[Ca][SO_4]$ or $[Ca][CO_3]$, stoichiometric values again being used. In considering the equilibrium between $CaSO_4$ and $CaCO_3$ it is possible to save one step in the calculation of data by using, instead of the mean molality, merely the products $[Ca][SO_4]$ and $[Ca][CO_3]$.

For all dilute solutions saturated with respect to anhydrite the values of some function of the product $[Ca]$ $[SO_4]$ plotted against the values of some function of the ionic strength should define a curve or a narrow band. In other words, the solubility of anhydrite as expressed in terms of $[Ca][SO_4]$ should be approximately constant for all solutions of the same ionic strength regardless of the specific composition of these solutions. For actual use it is convenient to plot log $([Ca][SO_4])$ and log $([Ca][CO_3])$ against $\mu^{1/2}$. If a sufficient number of complete analyses were available for solutions saturated at a given temperature with either anhydrite or calcite or both solid phases, it would be possible by plotting the results in the manner described to define a range within which points for anhydrite fall and another range in which the points for calcite fall. If these ranges were narrow, they might be represented by single curves. The equilibrium value of the SO_4-CO_3 ratio at any given ionic strength might then be determined from the difference in ordinate of these curves, since

$$\frac{[Ca][SO_4]}{[Ca][CO_3]} = \frac{[SO_4]}{[CO_3]}$$

for a solution saturated with respect to both anhydrite and calcite. Converting this equation to logarithmic form yields,

$$\log\left([Ca][SO_4]\right) - \log\left([Ca][CO_3]\right) = \log\frac{[SO_4]}{[CO_3]}$$

The difference in ordinate of the curves is then the logarithm of the desired equilibrium SO_4-CO_3 ratio.

[7] D. S. McKinney, *Ind. and Eng. Chem.*, Anal. Ed., vol. 3, 192-197, 1931.

The Evaluation of the SO_4-CO_3 Ratio

The method outlined was used in determining the SO_4-CO_3 ratio at 185 deg. cent. corresponding to a boiler pressure of 150 lb. per sq. in. gage. The resulting graphs of data are shown in Fig. 1. This

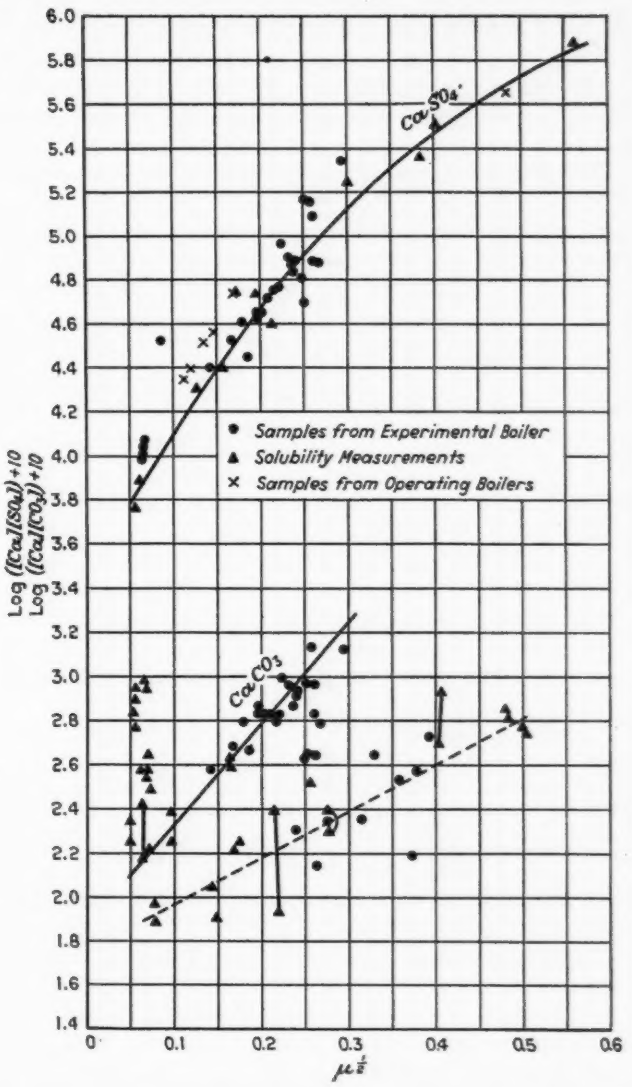

Fig. 1—Curves representing solubilities of $CaSO_4$ and $CaCO_3$ at 185 deg. Cent. (150 lb. per sq. in.) as a function of ionic strength of solution.

[Concentrations expressed in mols per 1000 grams H_2O were used in calculating values of log $([Ca][SO_4])$ and log $([Ca][CO_3])$.]

includes solubility values for calcium sulphate in pure water and in solutions of Na_2SO_4 and NaCl,[8,9] boiler-water analyses from actual boilers[5] which were known to be depositing either anhydrite or calcite or both substances, and a large amount of data from the experimental boiler operated in the laboratory by the authors. The individual data are presented and discussed in another paper[10] and only the general significance of the diagram will be treated here.

Discussion of Data. In spite of wide variations

[8] R. E. Hall, et al., Carnegie Institute of Technology, Mining and Metallurgical Investigations, Bulletin 24, pp. 59-67.

[9] E. P. Partridge, "Formation and Properties of Boiler Scale," University of Michigan Engineering Research Bulletin 15, 1930, pp. 42-43, 159-160.

[10] E. P. Partridge, W. C. Schroeder, and R. C. Adams, Jr., paper on "Direct Determination of the Sulphate-Carbonate Ratio for the Prevention of Sulphate Boiler Scale," submitted to *Industrial and Engineering Chemistry*.

in the composition of the various solutions the points for anhydrite define a curve fairly well. The points for calcite, however, spatter considerably. The authors see three possible explanations for this result. In the first place two crystal forms of calcium carbonate have been reported in boiler scale. These are aragonite and calcite, the latter being the more stable form. Presumably these two forms have differing solubilities. While aragonite is probably the less stable form under boiler-water conditions, it might persist for considerable periods of time. In addition, it is possible that fluctuations in boiler-water composition might cause reversal from calcite to aragonite although this is improbable. The second explanation, which seems plausible to the authors, is that the various solutions even at a temperature of 185 deg. cent. may remain supersaturated with respect to calcium carbonate for long periods of time and that the degree of supersaturation may vary considerably. The third explanation would be inaccuracy in the sampling methods and analytical procedure used in connection with the experimental boiler. Sampling was carried out with an internal filter and a cooling coil to reduce the filtered solution to room temperature before it was released from boiler pressure. All samples were guarded with the utmost care from contamination by the atmosphere. The authors believe that the values for Ca, obtained by the method involving precipitation as oxalate and titration with $KMnO_4$, and the values for CO_3, obtained by an evolution method rather than the customary titration methods, are accurate to within 1 p.p.m. Due to the small concentrations involved, the percentage error in these determinations is in many cases appreciable. The maximum analytical error in locating a point for $CaCO_3$ on the logarithmic ordinate of Fig. 1 should, however, not be more than ± 0.15, while the actual vertical spread reaches a value of 1.

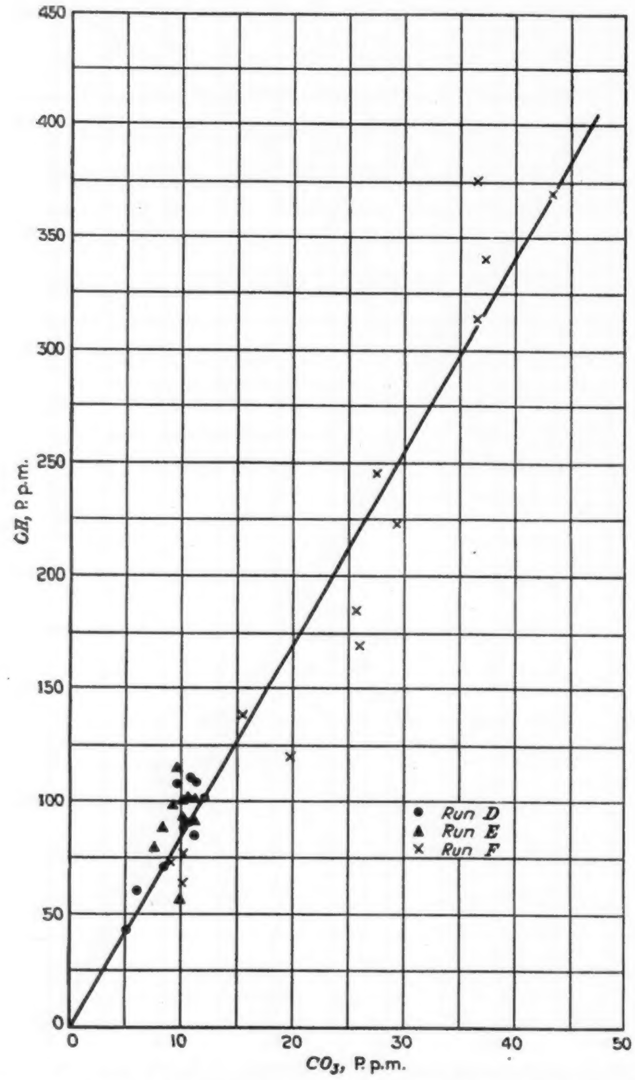

Fig. 2—Relation between CO_3 and OH in boiler-water samples from experimental boiler during scale-formation tests.

While the possibility of two crystal forms and uncertainty in analysis, coupled with the probability of supersaturation, render it impossible to draw a single curve representing the solubility of calcite in complex solutions, it is possible to draw a straight line through the upper range of the values. Since this line represents the maximum concentrations with respect to $CaCO_3$ obtained in the investigation, the use of values on this line in the calculation of the SO_4-CO_3 ratio will yield a value of the latter which is safe, although it may not be the precise equilibrium value which might be obtained by extremely refined methods.

The broken line drawn through the lower range of points for $CaCO_3$ may possibly define approximately the solubility of the less soluble of the crystal forms of $CaCO_3$, but the authors do not wish to stress this suggestion. The solubility curves of both aragonite and calcite may, however, be reasonably assumed to lie within the region bounded by the solid and the broken line.

At the lowest values of the ionic strength there are a number of high points for $CaCO_3$ which represent solubility measurements in the closed experimental boiler used as an autoclave at 150 lb. pressure. This was initially charged with solid $CaCO_3$ and distilled water. During the course of the experiment the value of log ([Ca] [CO_3]) dropped irregularly to a value on the solid line and then increased again. On addition of Na_2CO_3 with corresponding increase in the ionic strength of the solution much lower values were obtained along the broken line. A second solubility experiment yielded the sets of paired values shown which indicate less initial supersaturation than was evident in the first experiment.

A New Value for the SO_4-CO_3 Ratio

At 150 lb. per sq. in. gage pressure the value of the SO_4-CO_3 ratio calculated by Hall is 11. Much higher values are obtained from Fig. 1 by using the curve for $CaSO_4$ and the solid line through the upper range of points for $CaCO_3$. These values are indicated in Table 1 for various values of $\mu^{1/2}$. Due to the arbitrary use of a straight line through the $CaCO_3$ data, the calculated values of the ratio vary with the ionic strength. While the exact value of the ratio is in doubt, the authors feel quite safe in

stating that it is at least 100, and may be appreciably greater.

The conclusion that the SO_4–CO_3 ratio has a value greater than 100 is substantiated by the results from controlled scale-formation tests made in the experimental boiler. The significant data from three runs are shown in Table 2. During runs *D* and *E,* which lasted 12 and 13 days, respectively, the solution fed to the boiler contained approximately 55 p.p.m. $CaSO_4$ and 55 p.p.m. Na_2CO_3, or slightly more soda ash than was theoretically equivalent to the concentration of Ca. After this water entered the boiler, $CaCO_3$ was precipitated as sludge, but the reduction in Ca concentration thus effected was not sufficient to prevent the formation during both runs of very thin layers of anhydrite scale on the hot tube, across which heat was being transferred at the rate of 39,000 B.t.u. per sq. ft. per hr. No attempt was made during these runs to control the SO_4–CO_3 ratio, which varied during run *D* from slightly above 100 up to 162 and then down to slightly less than 100, and during run *E* from slightly above 100 to 265 and back down to 179. Since at some time during each of these runs the boiler water must have been depositing not only $CaCO_3$ sludge, but also $CaSO_4$ scale, the "equilibrium" SO_4–CO_3 ratio must lie somewhere in the range of values calculated from the boiler-water analyses made during the runs.

TABLE 1.—VALUES OF SO_4-CO_3 RATIO FOR PREVENTION OF SULPHATE SCALE AT 150 LB. PRESSURE AS CALCULATED FROM FIG. 1

$\mu^{1/2}$	10 + log([Ca][SO_4])	10 + log([Ca][CO_3])	Δ log	SO_4-CO_3 ratio mols	SO_4-CO_3 ratio p.p.m.
0.10	4.10	2.34	1.76	58	93
0.15	4.39	2.56	1.83	68	109
0.20	4.67	2.79	1.88	76	122
0.25	4.91	3.02	1.89	78	125
0.30	5,13	3.25	1.88	76	122

TABLE 2.—DATA FROM SCALE-FORMATION RUNS IN EXPERIMENTAL BOILER AT 150 LB. PRESSURE

Run	Time, hr.	SO_4, p.p.m.	CO_3, p.p.m.	SO_4-CO_3, ratio	Composition and thickness of scale produced
D	32	537	5.1	105	Ca 27.9
	78.5	734	6.1	120	CO_3 3.3
	102.5	865	8.4	103	SO_4 66.8
	175	1580	12.0	132	R_2O_3 2.7
	198	1625	11.3	144	Thickness 0.003 in.
	223	1550	9.6	162	
	244.5	1485	10.8	138	
	271.5	1105	10.6	104	
	289	1070	10.2	105	
	289	1050	11.2	94	
E	100	1018	9.9	103	Ca 26.1
	124.5	1537	10.0	154	CO_3 2.9
	144.5	1875	11.2	167	SO_4 66.0
	198	1933	9.1	212	R_2O_3 8.7
	220	2517	9.5	265	Thickness 0.006 in.
	246	1810	8.2	220	
	268	2060	10.5	196	
	312	1810	10.1	179	
	312	1968	11.0	179	
F	49	1400	10.2	137	Ca 26.4
	73	1330	9.1	146	CO_3 40.8
	93	1250	10.2	122	SO_4 3.8
	144	2360	15.5	152	R_2O_3 20.0
	168	2950	29.4	100	Thickness 0.002 in.
	192	3400	36.6	93	
	213	3720	37.4	100	
	240	3780	43.3	88	
	258	4150	36.6	113	
	313	2650	27.6	96	
	334	1430	25.8	56	
	358	1950	19.9	98	
	384	2025	26.0	78	

During run *F* an attempt was made to hold the SO_4–CO_3 ratio in the boiler at a value of 100 by varying the amount of soda ash added to the feedwater, which was a solution of calcium sulphate containing 48 p.p.m. $CaSO_4$. In spite of the fact that the ratio value was rather high during the first six days, the hot tube at the end of the 16-day run showed practically no calcium sulphate on its surface, the very thin deposit being almost entirely $CaCO_3$ and iron rust.

The fact that $CaCO_3$ was the solid deposited in run *F,* while the thin scales of runs *D* and *E* were almost entirely $CaSO_4$, seems definite proof that the safe value of the SO_4–CO_3 ratio is above 100. The authors feel that the next step should be experimental operation of a large boiler under close control to test the practical effects of maintaining high ratio values. Any work of this nature will be wasted effort, however, unless the SO_4 and CO_3 concentrations are determined more accurately than has been the custom in boiler-water control. The authors have elsewhere [11] described the development of an evolution method for total carbon dioxide with which very accurate values for CO_3 may be obtained, in contrast to the high results indicated by the phenolphthaleinmethyl orange or modified Winkler titrations. They have also noted the fact that turbidimetric determination of SO_4 may give high values for SO_4 in a boiler water even though the instrument indicates correctly with sulphate solutions containing no other substances.

Significance of the New Ratio Value

The great objection to the use of soda ash as a chemical for the internal conditioning of boilers has been the high alkalinity produced in the boiler water by the hydrolysis of carbonate. The difficulty encountered in maintaining the SO_4–CO_3 ratio set by Hall for the prevention of sulphate scale without overstepping the Na_2SO_4–alkalinity ratio recommended for the inhibition of caustic embrittlement has led in many cases to the substitution of various phosphate salts in place of soda ash as a conditioning chemical. It now seems probable, however, that the CO_3 concentration required by Hall's original calculation of the SO_4–CO_3 ratio was considerably larger than necessary, and there is a chance that soda ash may still hold an important place in boiler-water treatment.

The soda ash added as conditioning chemical to a feedwater may be thought of as divided into two portions. The first portion is that amount which is chemically equivalent to the Ca in the feedwater and which will be removed from solution in the boiler by precipitation as solid $CaCO_3$. The second portion is the excess of Na_2CO_3 which is necessary to maintain a given CO_3 concentration and hence a given SO_4–CO_3 ratio in the boiler water. It is this Na_2CO_3 which is largely responsible for the development of alkalinity, since the precipitated $CaCO_3$ is quite effectively removed from the scene of action. Obviously, if it is possible to decrease the amount of excess Na_2CO_3 used in a boiler, the alkalinity produced by hydrolysis will be correspond-

[11] W. C. Schroeder, E. P. Partridge, and L. F. Collins, "Determination of Carbonate and Hydroxide in Boiler Waters," submitted to Industrial and Engineering Chemistry.

ingly decreased, other factors remaining the same. Since the rate of hydrolysis of dissolved carbonate is rather rapid, it is much better practice to add Na_2CO_3 continuously at as even a rate as possible than it is to make large additions intermittently. In the latter case the concentration of CO_3 is temporarily raised to a high value, but drops rapidly to a very low value, resulting in an increase in OH concentration with but brief protection as far as the SO_4–CO_3 ratio is concerned. On the other hand, when the feed of Na_2CO_3 is accurately and continuously proportioned to the flow of feedwater to the boiler, the maximum benefit from the standpoint of scale prevention may be obtained with the minimum increase in OH concentration.

The results obtained in the experimental boiler were quite encouraging. If the OH concentration in the boiler water is plotted against the CO_3 concentration, for all of the boiler-water samples taken during runs *D, E,* and *F,* Fig. 2 is obtained. A straight line represents the data within its limits of accuracy. From this line $OH/CO_3 = 8.5$. That is, with the experimental boiler operating continuously at 150 lb. gage pressure and with an intermittent blowdown due to sampling of less than 0.5 per cent of the feed, the boiler water contained on an average less than 9 p.p.m. OH for each p.p.m. CO_3. If a boiler were operated under good control with an average ratio $SO_4/CO_3 = 100$ to prevent sulphate scale formation, and if, by careful proportioning of the soda ash used for conditioning, the ratio $OH/CO_3 = 8.5$ obtained in the experimental work were realized, then the embrittlement ratios[12] would have the values $Na_2SO_4/NaOH = 7.4$ and $Na_2CO_3/NaOH = 0.087$. The Na_2SO_4–NaOH ratio is far above the value of 2.5, which is believed to be the upper limit of the embrittlement range.

Looking at it from the other viewpoint, an SO_4–CO_3 ratio of 100 would allow the development of 24 p.p.m. OH in the boiler water for each p.p.m. CO_3 before the edge of the embrittlement range would be reached.

While these calculations are based upon small-scale work in an experimental boiler, and thus are subject to the criticism that plant operation never does succeed in duplicating laboratory results, the authors feel that there is no fundamental reason why any boiler operated at up to 150 lb. pressure under competent chemical control cannot be held in the region of boiler-water composition limited on the one hand by the maximum SO_4–CO_3 ratio allowable for scale prevention and on the other by the minimum Na_2SO_4–NaOH ratio which is believed to inhibit embrittlement. To the authors it even seems possible that boilers might be operated at higher pressures with soda ash as a conditioning chemical if any considerations made this desirable. In this connection, the original data upon which the curves of Larson[13] are based would be extremely valuable, since from them it should be possible to calculate rates of hydrolysis.

[12] F. G. Straub, Univ. Ill. Engr. Expt. Sta., Bull. 216, 1930, p. 77, fig. 41.

[13] Larson, R. F., preprint "Decomposition of Sodium Carbonate in Steam Boilers," Hartford, Conn., Meeting, The American Society of Mechanical Engineers, June, 1931.

MEETINGS and CONVENTIONS

A. S. T. M. New York District Members Will Meet With Divisions of A. I. M. E. on February 18

A meeting of the members of the American Society for Testing Materials in the New York Metropolitan District is planned for Thursday evening, February 18, when they will gather in a joint meeting with the Iron and Steel Division, Institute of Metals Division, and New York Section of the American Institute of Mining and Metallurgical Engineers. This joint meeting will be on the last day of the annual meeting of the A.I.M.E. which is scheduled for February 12-18. The joint meeting will be held in the auditorium of the Engineering Societies Building.

The general theme of the meeting will be on metals. Dr. F. O. Clements, President, A.S.T.M. and Technical Director, General Motors Research Laboratories, will discuss the subject "Limits of our Knowledge of the Properties of Metals." Professor H. F. Moore, Past-President, A.S.T.M. and Research Professor of Engineering Materials, University of Illinois, will address the meeting on "Test Results and Service Values of Metals."

There will be a demonstration of ten different tests of welds given by A. B. Kinzel and W. B. Miller, Union Carbide and Carbon Research Laboratories, Inc., and John J. Crowe, Air Reduction Laboratories, Inc.

These tests will be: Visual Inspections, Hammer and Anvil Nick-Break Test, Bending Test, Tension Test, Hardness Test, Specific Gravity Test, Stethescopic Test, Invisible Ray Test, Compression and Drift Test, and Hydrostatic Internal Pressure Test.

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American Society for Testing Materials will hold its annual convention at Chalfonte-Haddon Hall, Atlantic City, N. J., June 20-24. Secretary, C. L. Warwick, 1315 Spruce Street, Philadelphia, Pa.

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American Society of Mechanical Engineers will hold their spring meeting at Bigwin Inn, Lake of Bays, Ontario, Canada, June 27-July 1.

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National Electric Light Association will hold its annual convention in the Atlantic City Auditorium and Convention Hall, Atlantic City, N. J., June 6-10. Secretary, A. Jackson Marshall, 420 Lexington Avenue, New York.

Water Cooled Furnaces and Firing Methods

for Pulverized, Liquid and Gaseous Fuels

By G. W. GLENDON[1]

and

OTTO de LORENZI[2]

Following the first successful applications of pulverized fuel to stationary boilers about twelve years ago, improvements in furnace design and construction as well as in methods of firing proceeded with marked rapidity. These developments have increased the tempo of progress in the arts of combustion and steam generation to such an extent that present practice is many years ahead of normal expected development. In reviewing these developments, the authors pay special attention to the various methods of firing that have evolved and comment on their limitations and advantages. The accompanying illustrations are the best that have come to our attention and, in themselves, should constitute a valuable addition to the literature of present-day furnace design and methods of firing for pulverized, liquid and gaseous fuels.

THE application of water cooled furnace linings, to replace those of refractory material, has been one of the principal reasons for the success of the modern, high capacity, steam generating unit. With this type of construction the limitations, as to CO_2, furnace temperatures and heat liberation, are removed, to such an extent, that it is possible to use smaller volumes for the combustion chamber. By reducing the furnace volume requirements, greater steam generating capacity is obtained for a given space. In this manner it is possible to decrease building costs. This reduction in building cost will more than serve to offset the increased cost of the water cooled type of lining. In addition to the foregoing, the availability factor of the unit is materially increased, and maintenance costs become negligible because of the absence of refractory surfaces, which are subject to erosion and burning. In most instances, by capitalizing the savings in maintenance alone, it is possible to justify the installation of water cooled furnace linings.

In the early stages of the development of pulverized fuel firing, the most satisfactory results were obtained by projecting the fuel vertically downward into the furnace. The burners were of the natural draft type, and located in an arch forming the roof of a Dutch oven furnace, which extended several feet in front of the boiler. The distance from this arch to the furnace bottom or hearth varied from 15 to 25 ft. Approximately 15 per cent of the air, required for combustion, was supplied under pressure and served to transport the fuel from the feeders to the burners. The remaining, or secondary air, was supplied by induction through the burner casing, as well as through ports in the furnace walls. Full refractory linings were used. To minimize maintenance and at the same time secure fair availability, it was necessary to set relatively low limits on the furnace CO_2 and heat liberation. These limits were approximately as follows: lignites and mid-western bituminous coals 13.5 per cent CO_2 and 12,000 B.t.u. per cu. ft.; for Pittsburgh district coals, 14 per cent CO_2 and 13,000 B.t.u. per cu. ft.; for Pocahontas and New River coals, 14.5 per cent CO_2 and 14,000 B.t.u. per cu. ft. Even under these conditions, the furnace linings were washed away by the molten ash which acted as a flux with the refractory materials. Then too, the deposit of dust, on the furnace hearth, slagged and made cleaning an extremely difficult task.

To prevent the formation of slag on the furnace hearth, it was necessary to provide some means for cooling the ash, and then maintaining it at a temperature below its fusion point. After various experiments, this was accomplished by installing a series of water cooled tubes located in the furnace several feet above the bottom. After the efficiency of this method of cooling was definitely established, this water screen was tied into the boiler circulation and became an integral part of the unit. This design, more than any other one, was respons-

1 and 2, Combustion Engineering Corporation, New York.

ible for the ultimate success of pulverized fuel firing.

While the bottom water screen served to eliminate slagging difficulties on the furnace hearth, erosion of the furnace wall still existed. With increase in ratings and liberation, the walls were washed away more rapidly. In many cases the rear wall was subjected to particularly severe punishment. To minimize the effect of flame impingement at this point, the riser tubes from the bottom screen were carried up, inside the furnace, directly in front of the rear wall. These tubes were on relatively wide centers but they afforded sufficient protection to aid materially in reducing the maintenance at this point. The exposed refractory between these tubes, however, served as an anchorage for honeycomb slag formations. In time these would grow quite large and then break off, falling onto the lower screen and partially blocking it. If not removed, accumulating dust deposits would rapidly form slag masses. The cooling effect of the bottom screen would be lost and it was necessary to take the boiler out of service for furnace cleaning. This difficulty was overcome by completely cooling the rear wall, the center to center distance between the tubes being decreased.

Furnace side walls were the next to receive attention. Air cooling of the refractories by providing horizontal or vertical lanes, through which the secondary air was either induced or forced, gained much favor. This type of construction was more costly than the solid refractory walls. Its life, however, was materially longer and the reduction in outage and maintenance more than served to offset the increased first cost.

While the types of construction, previously cited, increased availability, it was not possible to raise the rates of heat liberation to any great extent. With coals having a fusion temperature of ash of over 2400 deg. fahr., 18,000 B.t.u. per cu. ft., for periods of 4 to 6 hours, was the safe maximum. When the fusion temperature of ash fell below 2400 deg. fahr. the safe maximum rate was approximately 16,000 B.t.u. per cu. ft. Furnace difficulties immediately followed any attempt to exceed these limits.

Because of the desire for higher ratings on boilers, furnaces became larger and larger. High refractory walls were difficult to design and support, because of the severe service imposed on them by excessive furnace temperatures. The next logical step was then taken and partial water cooling, of the side walls, was installed. At first it was felt that the addition of this heat absorbing surface, in the furnace, would serve to slow up the combustion reactions to the extent that ignition difficulties would be encountered. However, no change in the behavior of ignition was noted. It was now realized that complete cooling of the side walls would greatly increase furnace availability and also make possible operation at considerably higher rates of heat liberation. Several small furnaces, for increased duty, were installed. After they were put into operation, it appeared that the designers had overstepped their mark. Expected ratings were not realized. A number of experiments developed the fact that the burners, and not the furnaces, were at fault. To effectively burn the fuel at high rates of liberation, it is necessary to provide additional turbulence of the air and coal streams as they enter the furnace.

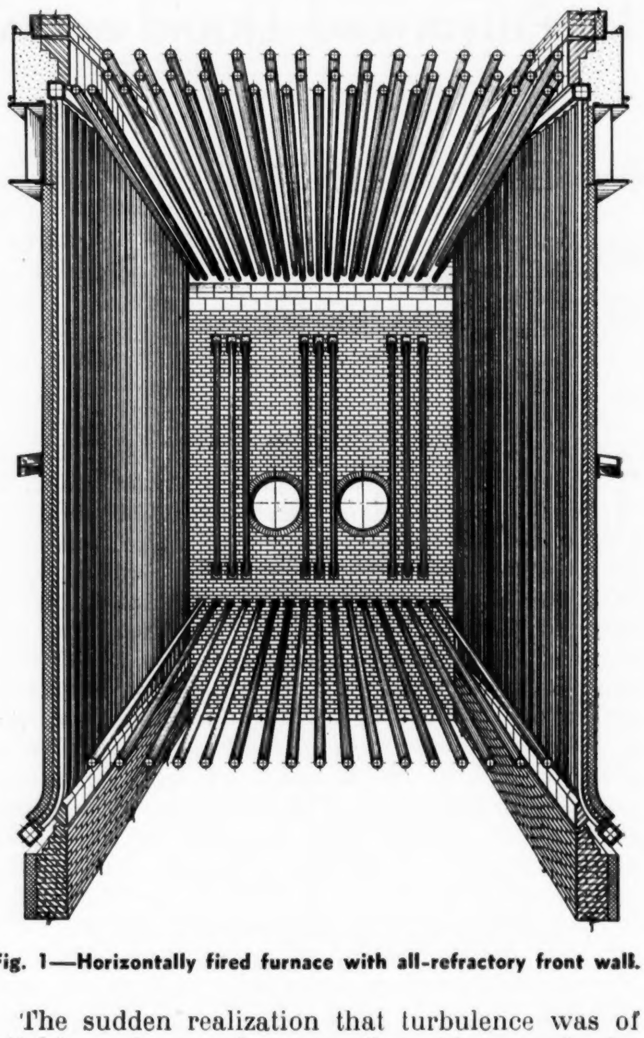

Fig. 1—Horizontally fired furnace with all-refractory front wall.

The sudden realization that turbulence was of vital importance, when operating at increased rates of heat liberation, was responsible for the rapid development in burner design. Many schemes were tried and three have survived.

Contrary to the general impression, vertical firing has not been abandoned. The burners have been redesigned so that air, under pressure, is supplied around the coal nozzles. The secondary air is supplied under pressure through the front wall. This causes the air to cut across the fuel stream at right angles. Intense turbulence is thereby set up in the furnace. These changes serve to decrease the length of flame travel required to the extent that it is possible to operate at rates of heat liberation well over 30,000 B.t.u. per cu. ft. In fact the maximum evaporation, from any single boiler unit to date has been obtained on a vertically fired installation. These particular units have an availability factor which exceeds that of the turbines which they serve.

The horizontal, forced draft type, of turbulent burner finds favor in many installations. In these,

the coal and primary air enter through a central nozzle which is provided with a diffuser. We therefore have a relatively thin hollow cone of primary air and coal. The secondary air is supplied, under pressure, through vanes located in such a manner as to cause the secondary air to cut across the fuel stream, as it emerges from the nozzle. The result is intense turbulence and complete combustion. Liberation rates up to 25,000 B.t.u. per cu. ft. have been maintained without difficulty. The principal advantage of this type of burner is its capacity, which may vary from 3,000 to 9,000 lb. of coal per hr. These burners are most effective over an operating range of 3 to 1. Because of this fact, they are not as suitable with a widely fluctuating load. To meet this condition, a number of smaller burners, of the vertical type, is a more satisfactory arrangement.

Probably the most important application, and the one which takes full advantage of turbulence, is the corner firing method. In this design burners are placed in the four corners of the furnace. The primary air and coal stream issuing from

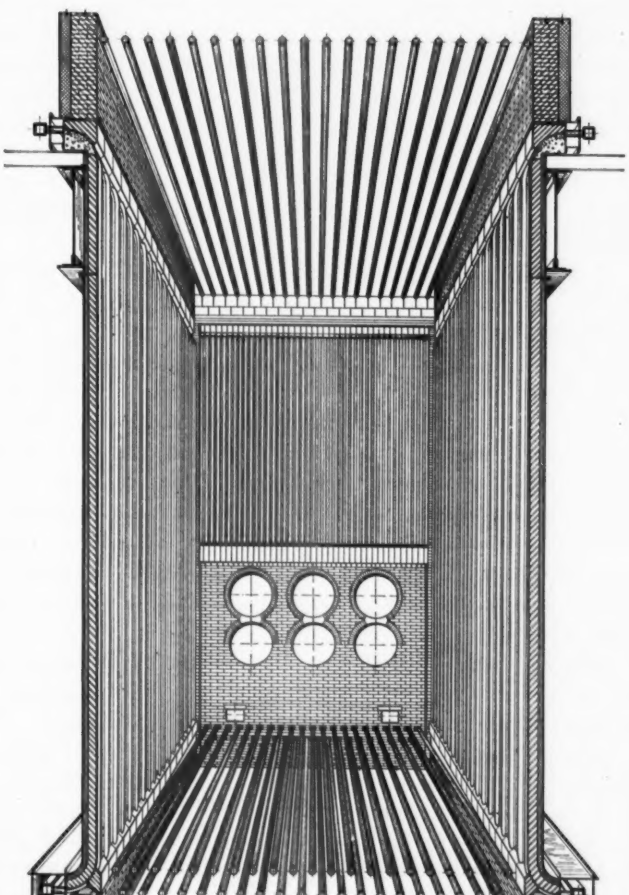

Fig. 2—Fairly large horizontally fired furnace with maximum water cooling for this arrangement.

them are directed along tangents to an imaginary horizontal circle, in the center of the furnace. The secondary air supply enters the furnace around the coal nozzles. In this manner turbulence is not only obtained at the point of entrance to the furnace but is continued until the combustion reactions are practically complete. It is possible to operate at extremely high rates of heat liberation with this design. In one instance, when burning wet washed blast furnace gas, no ignition or combustion difficulties were experienced at 38,000 B.t.u. per cu. ft. This performance is very remarkable when the nature of the fuel is taken into consideration, as it is extremely lean and notorious for its slow burning characteristics.

While the maximum combustion rates for the three types of burners, previously described, are considered high, they do not approach those existing in marine and locomotive operation. It is common practice to operate a marine, water cooled, furnace at 135,000 B.t.u. per cu. ft. Under normal working conditions the rate of heat liberation may exceed 300,000 B.t.u. per cu. ft. in a locomotive furnace. However, these extremes are dictated by necessity and not choice. The amount of pay load that it is possible to transport by boat or train is the governing factor in design. Stationary boiler furnaces have never been operated at these capacities. Future designs may serve to reduce the difference between present practice and the extremes just cited. It is seriously doubted that it will be practical to economically exceed 50,000 B.t.u. per cu. ft. under any condition which may exist in stationary plants.

There are now available a number of different types of water cooled furnace constructions. These may be broadly divided into the covered and the bare tube design. In the one, tubes are placed on relatively wide centers and then covered with some form of block, which makes contact with the tube surface. In the other, bare tubes are placed on relatively wide or narrow centers and refractory or other material placed between, or behind, them. In the case of the covered type of wall, the amount of heat transmitted to the water, in the tube, depends on contact between the tube and the block. In the bare tube construction the heat absorbing surface is water swept and thus transmits its heat directly to the absorbing medium. Under the same furnace conditions, as to liberation and CO_2, the bare tube wall will absorb more heat per square foot of exposed surface than the covered type of wall. This increase in absorption will vary from 30 per cent at low rates of liberation, to 60 per cent at high rates. This is of major importance. It influences temperature, which is a function of liberation, CO_2 and rate of heat absorption by the walls, and thus affects the size and design of furnaces.

The amount of water cooling applied to a given furnace is governed, largely, by the size of the furnace, the maximum heat liberation, the type of burner, the character of the fuel and the load.

Horizontal turbulent burners are usually placed in the front or rear wall of the furnace. This wall may be all refractory or partially water cooled. If the liberation is to exceed 20,000 B.t.u. per cu. ft. the remaining three sides of the furnace should be water cooled and a hearth screen provided. If

the heat liberation exceeds 22,000 B.t.u. complete cooling should be provided.

If we look towards the burner wall of a horizontally fired furnace it will appear similar to Fig. 1. In this instance, it will be seen that a minimum of water cooling is provided, in the vicinity of the burners. The nine tubes shown are the riser connections from the hearth screen. They are brought into the furnace to give some protection to the front wall refractories.

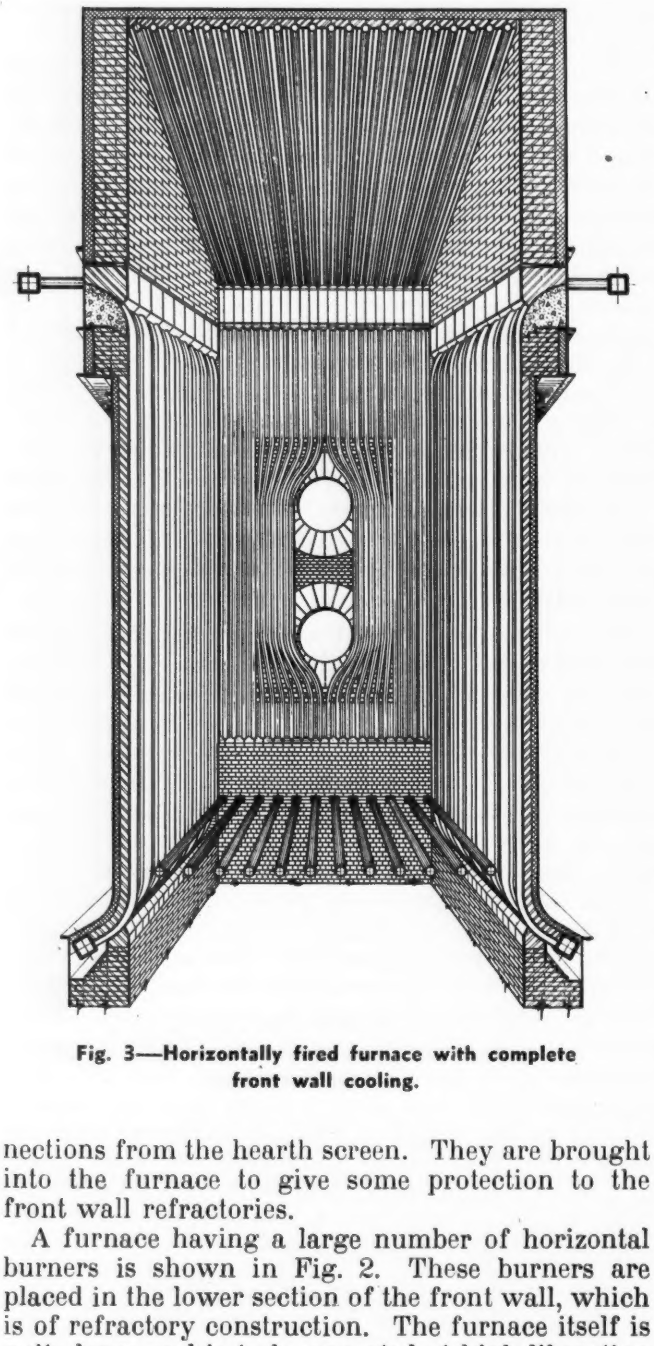

Fig. 3—Horizontally fired furnace with complete front wall cooling.

A furnace having a large number of horizontal burners is shown in Fig. 2. These burners are placed in the lower section of the front wall, which is of refractory construction. The furnace itself is quite large and is to be operated at high liberation rates. A maximum amount of water cooling is provided by covering the upper part of the burner wall, as well as the remaining walls with bare tubes. Because of the large number of burners it is not practical to provide cooling for the lower section of the wall.

The horizontally fired furnace illustrated by Fig. 3 has practically no exposed refractory surfaces. The construction shown is made possible by the fact that two burners, placed one over the other, are provided. The wall tubes are bent around the burners. While this design is more costly the practical elimination of maintenance and outage will serve to offset this in a comparatively short time.

The general practice, in the case of vertical firing, has been to omit water cooling in the front furnace wall. A number of installations have been made, however, where the entire furnace, including the arch over the Dutch oven extension, has been water cooled. In these the secondary air enters the furnace through a large number of ports located between the tubes of the front wall. The tertiary air is supplied through the burner casing around the coal nozzle. The primary air is used to transport the coal from mill, or feeder, to the burner. The amount and pressure of the tertiary, and secondary air, is adjusted to the particular coal being burned. With this arrangement prompt ignition is secured and a wide variety of fuels are handled with no difficulty.

The furnace shown in Fig. 4 is of the vertically fired type. Complete water cooling, of the bare tube type, is provided. Notwithstanding the refrigeration effect of the large amount of heat absorbing surface, in the furnace, coal containing not more than 21 per cent volatile matter has been burned with the same ease as that containing from 28 to 32 per cent. Carbon losses, over long periods of operation have rarely, if ever, exceeded 1 per cent. The furnace CO_2 is constantly maintained above 15 per cent.

A completely water cooled furnace is necessary where corner firing is used. The continuation of turbulence in the furnace, after the fuel and air mixture leaves the burners, causes a sweeping action of the gases over the walls. This has the effect of continually removing the relatively cool and inert gas film. The walls are maintained in a condition capable of high rates of heat absorption. Because of the intensity of turbulence, and temperature, it is necessary to provide the bare tube wall construction. Any other type, because it cannot take the surface heat away fast enough, would fail in a short while.

In Fig. 5 the simplicity, in design, of the corner fired furnace is well illustrated. All four walls are completely covered with straight bare tubes. A minimum amount of refractory is provided in the corner, for the installation of the burners and access doors. In a number of installations practically all of this refractory has been eliminated, by bending tubes around the burner and door casings.

Furnaces of this type have been operated over a period of several months at rates of heat liberation in excess of 37,000 B.t.u. per cu. ft. of total volume. However, because of the intensity of turbulence, and the resultant speeding up of the combustion process, the visible flame occupied, approximately, the lower 30 per cent of the total volume provided. The sweeping action of the flames and the intensity of turbulence result in extremely high rates of heat absorption by the furnace walls. This serves to lower the temperature of the gases, as they leave

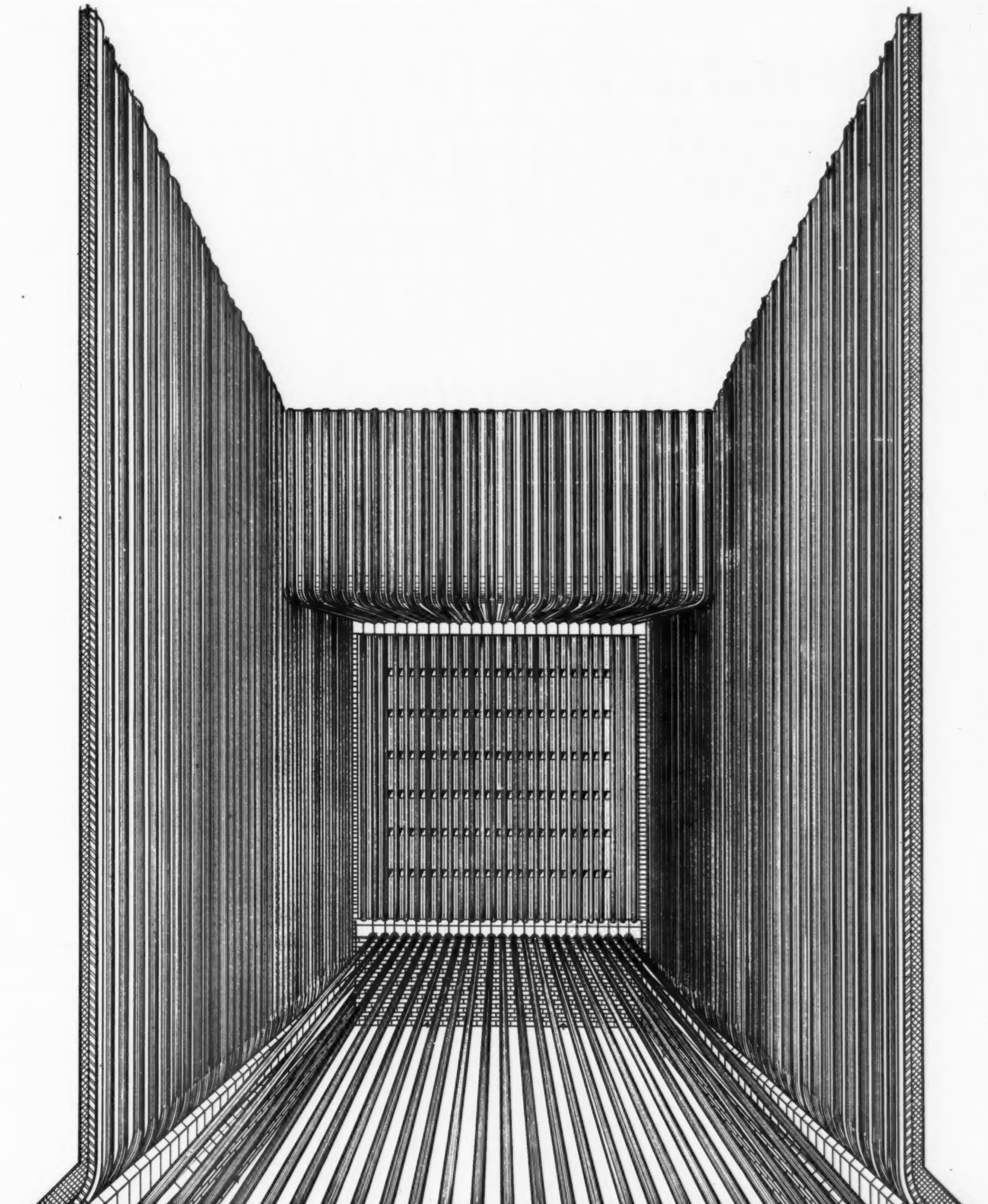

Fig. 4—Vertically fired furnace with complete water cooling.

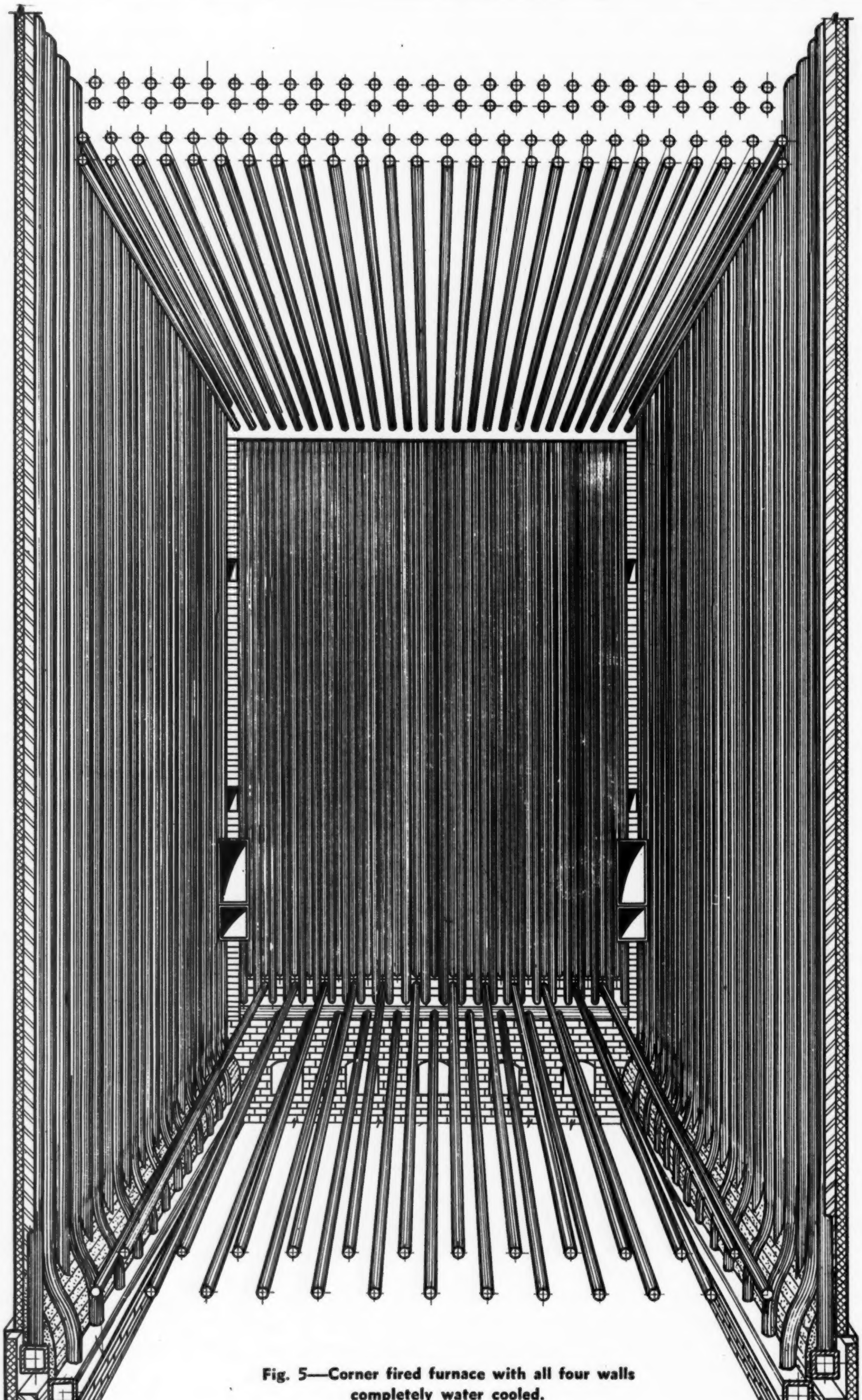

Fig. 5—Corner fired furnace with all four walls completely water cooled.

the furnace, to a point below which melting of the ash particles does not occur. This is a vital factor in maintaining a high availability factor as deposits of honeycomb slag in the boiler are eliminated.

When burning gaseous, liquid or solid fuels, at high rates of heat liberation, it is necessary to provide means for maintaining the furnace temperature sufficiently low so as to minimize repairs and outage. At the same time the operation must be carried on without resorting to the use of excess combustion air, and the resulting increase in heat loss which naturally follows this procedure. The bare tube type of wall is the ideal design for meeting these conditions, and at the same time it possesses further advantages. The construction is such, that because of the smaller furnace volume required, it actually becomes an integral part of the steam generating unit. The addition of this extremely active surface in the furnace serves to decrease the duty on the convection section of the boiler. At the same time full advantage can be taken of the fuel burning equipment. Ratings may be increased, to a point corresponding to the maximum draft available.

Many engineers have felt that with the bare tube type of wall, the carbon loss in the ash pit, and up the stack, would be excessive. Operating results, in a number of large utility plants, over a period of several years, show this loss to be no greater, and in some cases much less, than in refractory furnaces. The method of air and fuel admission are the important factors in maintaining this loss at a low figure. Because the exterior wall surfaces are at a lower temperature the radiation and convection losses, from this source, are decreased. The reduction in furnace size makes it possible to install efficient high capacity units in a limited space. This means an actual saving in land and building investment.

The coordination of furnaces and fuel burning equipment is of major importance. The haphazard application of water cooling will, in many instances, become a source of serious operating difficulties. On the other hand, a correctly designed water-cooled furnace will be remarkably free from such difficulties and will assure the maximum of availability and performance with minimum maintenance. However, the attainment of such results is only possible when the design is based upon broad experience with many installations.

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Southern California Edison Company announces the following promotions: George C. Ward, executive vice-president, under whose direction large hydro-electric and steam-plant developments of the company have been completed, was recently made senior vice-president; William C. Mullendorf, vice-president was advanced to the post of executive vice-president, and Fred B. Lewis, vice-president and assistant general manager, was made vice-president and general manager.

The Norton Company, Worcester, Mass., honored its president and general manager Charles L. Allen, by a dinner commemorating the completion of his fifty years of leadership in the company. Congratulatory letters were received from President Hoover and former President Coolidge. Also, on that occasion King Gustav V of Sweden conferred on Mr. Allen knighthood of the first class in the Order of Vasa in recognition of his contribution to the development of friendly relationship between the United States and Sweden.

Mr. Allen became connected with the business in 1881, shortly after the emery wheel was first put to commercial use and has served the Norton Company ever since in various executive capacities, becoming president in 1919. During his incumbency the business has grown to a plant occupying more than 2,000,000 square feet floor space in Worcester with other plants in Arkansas, Ontario, England, France and Germany, and with representatives all over the world.

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Samuel Insull, Jr., president of the Midland United Company, Chicago, was elected vice-chairman at a recent meeting of the board of directors. Robert M. Feustel, executive vice-president of the company and chief operating head of the subsidiaries, was elected president to succeed Mr. Insull, and Wm. A. Sauer, previously vice-president and general manager, was elected executive vice-president.

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Riley Stoker Corporation announce the appointment as sales engineers of J. H. Rohrer and H. W. Hendrix, who will be located at Philadelphia.

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Combustion Engineering Corporation, New York, announces that J. D. Harrison, district manager of the Chicago office from 1922 to 1929, has been reappointed to that position effective January 1, with offices in Bankers Building, Adams and Clark Streets, Chicago.

Mr. Harrison will succeed Mr. Hugh R. Carr, who has been transferred to the Sales Department of the home office at New York as Manager of Stoker Sales.

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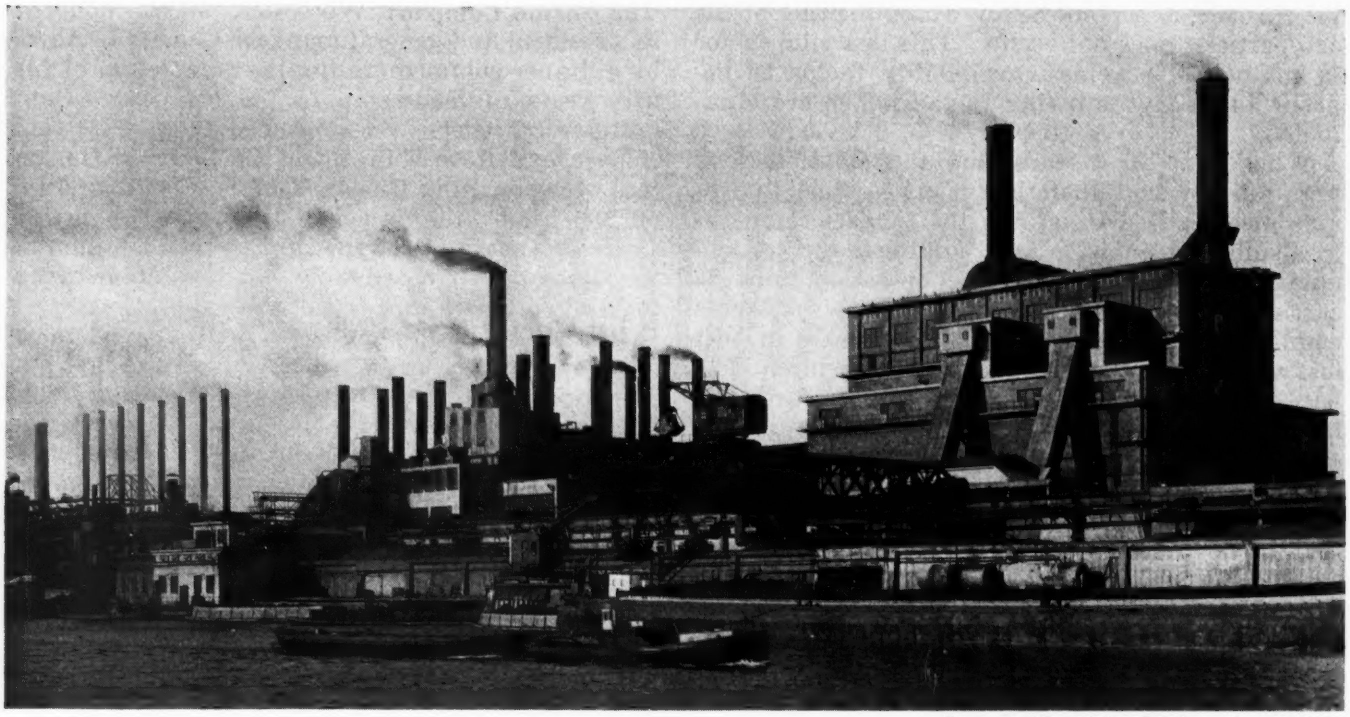
General Electric Company announces the appointment of Everett Lee, engineer in charge of the laboratory at Schenectady, to succeed the late Lewis T. Robinson. Mr. Lee joined the company in 1913 and then went to Union College as an instructor in electrical engineering. After the World War, he entered the G. E. laboratory and was made an assistant engineer in 1928. Dr. J. J. Smith has been appointed to succeed Mr. Lee as one of the assistant engineers.



Centrale Noord 11 Station, Amsterdam

The Centrale Noord 11 Station at Amsterdam

By DAVID BROWNLIE, London

Mr. Brownlie describes a recently-built power station in Holland. Although this station is relatively small, as judged by American standards, it is fairly representative of modern practice and apparently is obtaining results comparable with the more efficient stations elsewhere. The author gives some interesting sidelights on the extent of electrification and the general industrial situation in Holland.

CONSIDERABLE interest attaches to the new Centrale Noord 11 Station of the Amsterdam Corporation (Gemeente Electriciteitswerken, Hoogte Kadijk 200, Amsterdam), which was opened officially in October 1930, having been under construction since September 1928.

This represents the latest Dutch practice in the power station field, and Dr. W. Lulofs, the Chief Engineer and Manager, whom I have to thank most sincerely for the photographs reproduced and much other kind assistance, is a well-known European power station expert who has not only decided views of his own in this connection but also carries them out in practice. For example, he was one of the main pioneers of the general principle of combining the operation of traveling grate stokers with "unit" pulverizers, and right from the early days of pulverized fuel firing he has always been a very pronounced advocate of the unit or direct-fired method of burning pulverized fuel.

This Centrale Noord 11 Station is built on the banks of the Johan van Hasselt canal, adjoining the older Centrale Noord 1 Station, which latter is now operated to take the peak loads, the No. II Station being the base line installation.

The essential features of the new plant may be summed up as medium-size boilers, relatively low steam pressures and temperatures of superheat, unit pulverizers throughout, operating with low volatile coal, fine grinding, special design of water-cooled furnaces with all four walls of this construction, combined individual steam-turbine and electric-motor drive on the same shaft for the important auxiliaries, including pulverizer mills, fans and pumps, an elaborate system of feedwater heating with the use of the exhaust steam on the 2-stage principle from the turbine side of the auxiliaries, 2-stage main bleeder heating, an exceptionally well equipped control board, small turbo-alternators,

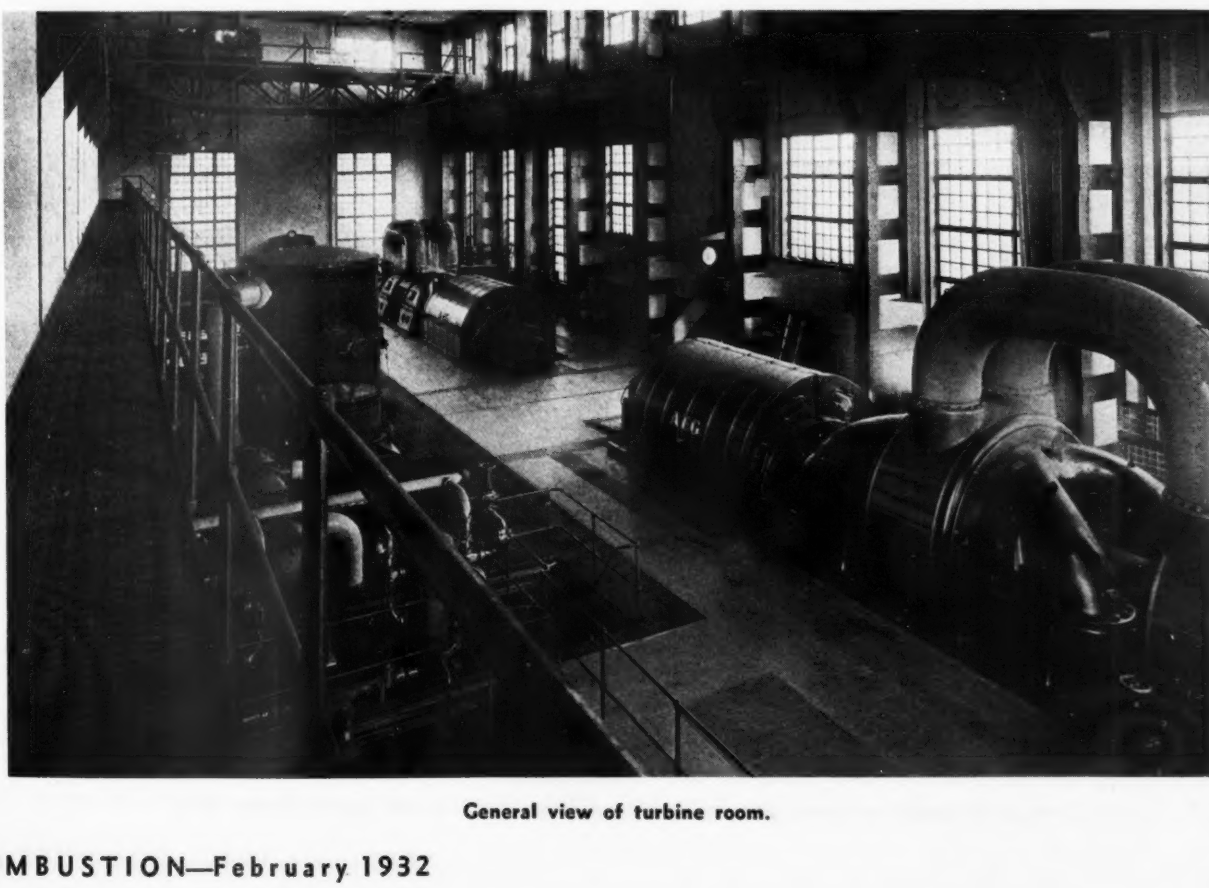
and low capital cost, especially in view of the good thermal efficiency which is believed to obtain.

The boiler plant at Centrale Noord 11 consists of three boilers, respectively of "B. & W.," "Stirling," and "Hamomag" make, the latter having been constructed by the Werkspoor Company of Amsterdam. Each boiler has a normal evaporation of 190,000 lb. of water per hour with a maximum overload capacity up to 265,000 lb. per hour, running at 450 lb. per sq. in. pressure and 765 deg. fahr. superheated steam temperature. The water-cooled furnaces are constructed to the design of Dr. Lulofs, with the water screens in two divisions sloping down to the bottom of the chamber, the total volume of which is 21,895 cu. ft. Also each boiler has integral superheater, air heater, gill tube feedwater economizer, and dust arrester, and is operated with two forced and two induced draft fans. Further, the main heating surfaces for each boiler setting are 13,993 sq. ft. for the boiler, 7,395 sq. ft. for the furnace walls, 7,028 sq. ft. for the superheater, 11,884 sq. ft. for the economizer, and 17,653 sq. ft. for the air heater. The three boilers are served by two steel stacks.

Each boiler has four pulverizers and eight burners, that is two burners per pulverizer. The burners are located at the top of the combustion chamber in the case of two boilers, pointing at a sharp angle downwards, while in the other boiler the burners are located near the bottom and fire almost horizontally. Also the normal throughput of each unit pulverizer is 2.2 tons of coal per hr., that is 8.8 tons per boiler, and the degree of grinding is finer than usual, being equivalent to 85 per cent through a 200 mesh screen. As a rule, coal of a semi-anthracitic character is used, below 15 per cent volatile, and it is stated that anthracite can also be used. As usual, also in modern practice, the coal is dried direct in the pulverizers by means of a mixture of very hot flue gases and cold air, giving an average temperature actually in the mill of approximately 390-480 deg. fahr.

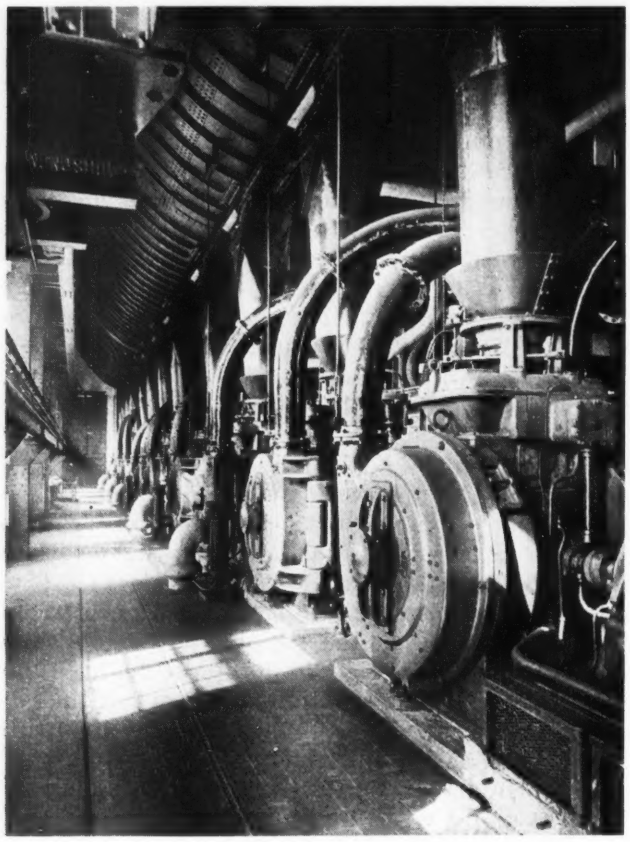
As already stated, the drive for the pulverizers, fans, and pumps is on the combined steam-turbine and electric-motor principle, with the exhaust of the turbines when running used to supplement and control the feedwater heating, which is accomplished chiefly by bleeder steam from the main turbines. The pulverizer mills run at 1250 r.p.m. through reduction gearing, but because of the number of these mills every alternate unit has electric drive in addition to the steam-turbine drive with which every mill is equipped, these small turbines running at 3000 r.p.m. and operating through reduction gearing. Further, it may be stated that all accessory units driven in this manner with combined electric motors and steam turbines are fitted with automatic gear, so arranged that if the electric drive fails the turbines automatically start up, although in normal running the latter are used to adjust, as required, the supply of the total feed-heating steam necessary to maintain the high thermal efficiency of the station, while when the electric motor is running in any given case the turbine shaft is run as an "idler."

The primary air enters the furnaces through the burners along with the pulverized coal, while the secondary air is taken through the inlets in the furnace walls. Initial ignition is obtained by means of oil burners.



General view of turbine room.

The general operation is said to be very satisfactory, giving on the average 16 per cent CO_2, although performance details of the Centrale Noord



View of pulverizing plant.

11 Station have not yet been made public. As regards ash handling, this is carried out on the "Hydrojet" water sluice principle, the fine ash falling from the bottom of the furnaces into special hoppers having hand-operated ash gates, so that the whole of the material is completely quenched with water and is taken away by a water sluice, operated on the intermittent principle, generally for a short period every day. This arrangement is claimed to result in reliability and low operating costs. The sluice is of the horizontal type, running the whole length of the boiler house, the ash and the water passing out to a concrete settling sump on the side of the canal, 90 ft. long and 20 ft. wide. From here the quenched ash is removed by a traveling crane running on rails, which has a handling capacity of 50 tons of material per hour and operates a grab bucket, which discharges to barges on the canal.

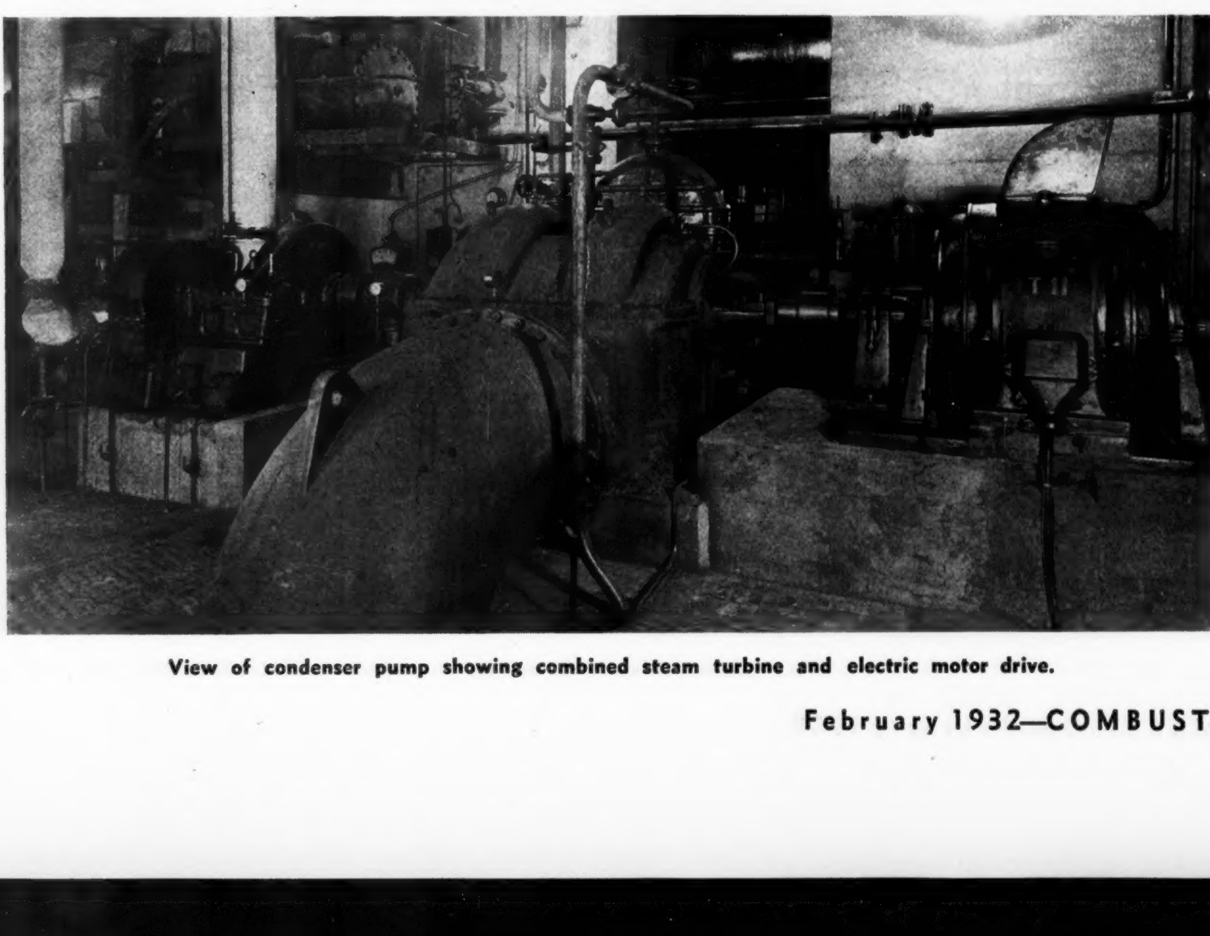
The "Modave" dust separator consists of vertical steel tubes in the gas flue to the chimney. A thin film of water runs down around the outside of these tubes continually and as the gases follow a "staggered" path between the tubes, the water effects separation of the dust.

As regards the coal handling and storage arrangements, the coal arrives in barges and the coal handling plant, which has a capacity of 45 tons per hour, delivers it to a main overhead bunker of 600 tons total capacity. This bunker is divided into three sections, one for each boiler, of 200 tons capacity each. Delivery of coal can also be made to a main store of about 40,000 tons capacity, while there is a further reserve store of 12,000 tons, making a total of 52,000 tons. Automatic coal weighers are used throughout.

The turbo-alternator plant consists of two units, each of 25,000 kw. capacity, with one turbine by Ascher Wyss & Co. of Zurich, Switzerland, and the other by Gebrüder Stork & Co. of Hengelo, Holland, each running at 3000 r.p.m., while in both cases the alternators are by the A.E.G. Company of Berlin. Ample cooling water is available from the adjoining canal, and it is stated that 96 per cent total vacuum is obtained.

Holland has always been an advanced country from the engineering point of view, not only with

(Continued on page 44)



View of condenser pump showing combined steam turbine and electric motor drive.

Brooklyn Edison Boiler Installation Nearing Completion

The Story of the Erection of one of the Largest Boiler Contracts ever Placed

By G. F. GREENE, Field Engineer
Combustion Engineering Corporation, New York

The work of erecting large steam generating units to meet a definite schedule requires thorough organization in advance of field work to assure completion of manufacture and shipment of materials at the proper times, and expert supervision in the field. Frequently field problems arise that cannot be foreseen and that involve serious loss of time unless they are met with exceptional ingenuity and resourcefulness. In other cases local conditions, such as existing building structures and limited storage space, constitute severe handicaps . . . The story of how such difficulties were met and overcome in the erection of eight new boiler units at the Hudson Avenue Station of the Brooklyn Edison Company is told in this article, the author of which was in direct charge of the field work. This job, one of the largest of its kind to date, is now nearing completion and, at the present stage of progress, is well within the program scheduled.

IN December of 1930, erection work was begun on eight new steam generating units for the Brooklyn Edison Company at their Hudson Avenue plant which fronts on the East river. The contract for the eight bent tube boilers, awarded to Combustion Engineering Corporation, also included superheaters, waterwalls, economizers, soot blowers, settings, boiler and furnace casings. The stoker equipment for these boilers was covered on a separate contract awarded to the American Engineering Company.

The object of this article is not so much to give the size, capacity and operating conditions of these boilers as it is to give some idea of the immense amount of material handled in a short time with comparatively small storage space and to describe some of the principal problems and show how they were met.

In conferences prior to the beginning of erection work, it became obvious that there were a number of conditions that would have to be maintained. The most important of these were that, at all times, the plant dock should be kept free of material and that the center aisle in the boiler room basement should be kept clear so as to allow trucks to pass through to the dock, the latter being necessary on account of a roadway being blocked for repairs to the bulkhead.

In order to meet these conditions, it was necessary for shipments of material to be scheduled very carefully and that the plants shipping the material adhere strictly to the schedule so that the erection force would be able to plan its work in such a way that, as soon as material was received, it could be unloaded, removed and erected into place. The position of the boiler house with relation to the dock is such that a truck could not operate efficiently in unloading lighters, due to the short haul. Consequently, all material, with the exception of the boiler drums and a few of the heavier headers which were pulled in on skids, had to be handled manually. This meant that a considerable number of men had to be employed continually handling material on arrival.

In order to illustrate what this involved it might be of interest to review some figures showing how much equipment has been handled. At the beginning of the job it was estimated that approximately 5,000 tons of material would be shipped during the process of erection. The actual erection work started on Dec. 12, 1930. In the original program it was estimated that about 14 months would be required to complete erection, and up to date (January 6, 1932) approximately 4,585 tons of material, exclusive of brick work and building steel has been shipped, unloaded and erected.

This result could only be accomplished by carefully planning the work ahead and by getting each gang organized to specialize in its particular job. It was decided that each gang of men, under a foreman would be assigned to the same work on

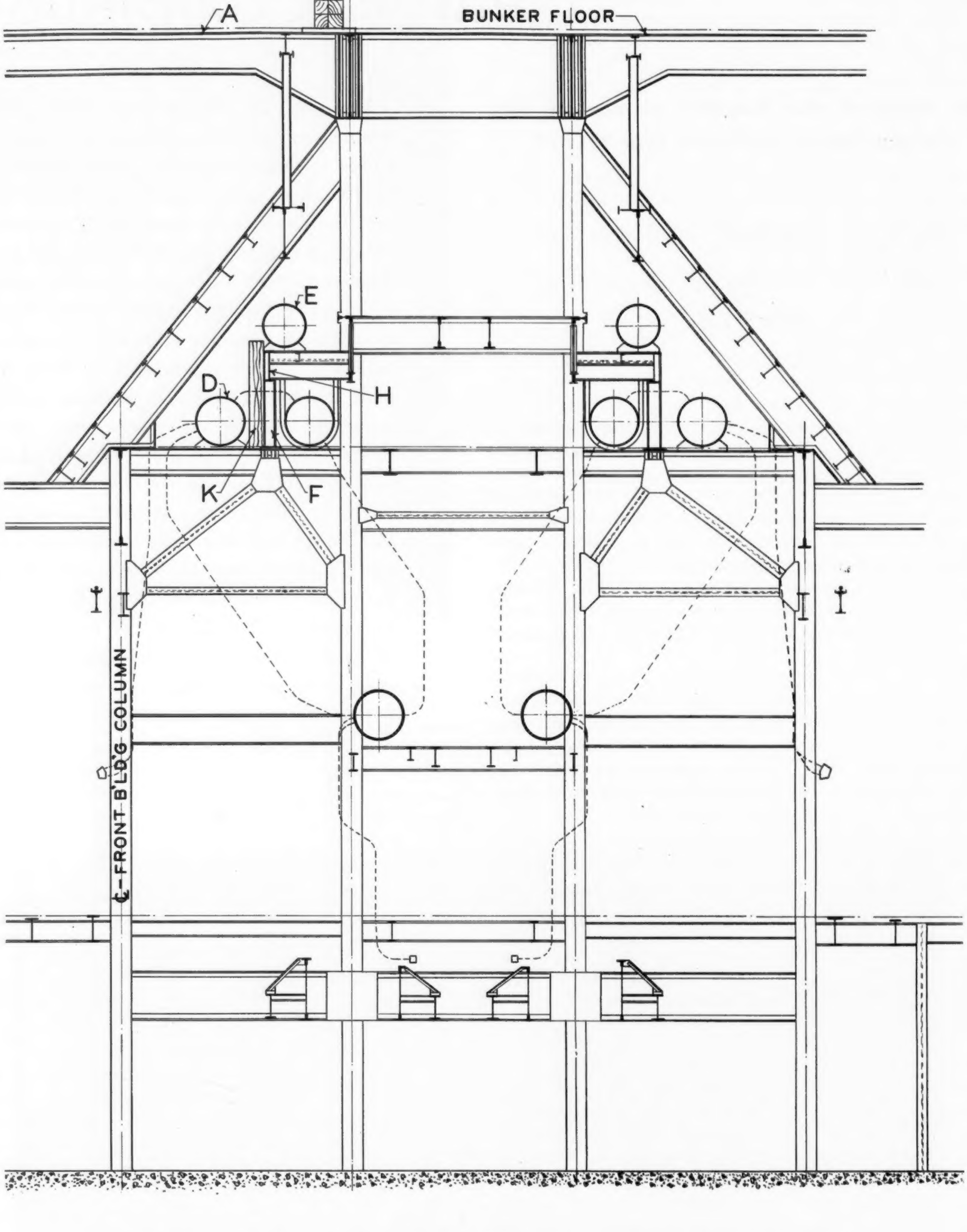


Fig. 1—Sectional elevation of two of Hudson Avenue Units, showing principal steel-work and location of boiler drums.

all units, and, as far as possible, would do nothing else but that. For instance, one gang would hoist drums, another set the drums, another would install tubes and another roll tubes. By organizing in this manner we were able to handle two lighters of material a day, and in one case, three lighters were unloaded between 8 A.M. and 4:30 P.M. on one day which was a record for this plant. In spite of the above, at no time was either the dock or aisles blocked so as to hold up either our own work or that of other contractors.

Before describing the erection work, it may be of interest to give some figures indicating the size and weight of the units. Each unit is comprised of four drums, each weighing between 30 and 40 tons. The boiler tubes for all eight units, if placed from end to end, would reach over 51 miles—the waterwall tubes would stretch over 10 miles—the circulating tubes over 25 miles and the economizer tubes over 11 miles.

When work was started, it was planned to erect the drums for four units only and to complete these units before proceeding with the balance of the contract, so that neither the customer nor other contractors would be blocked by our work. However, after the drums for the second unit had been partially erected, and the customer shown that we would not block anyone, permission was given to proceed with the erection of the drums for the entire contract. All drums were erected in place by March 15th. Work then stopped on the last row of boilers until about July 15th, all attention being given to finishing the first four units.

One of the first problems that had to be solved in starting erection was the hoisting of the boiler drums. The original plan was to use the large girder under the coal bunker as a support for the cable sheaves by means of beam clamps. However,

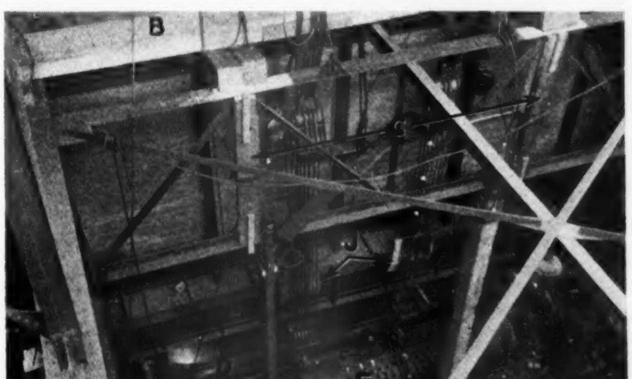


Fig. 2—Hoisting drums.

after considering the design of steel and the relative positions of drums and steel, this method of hoisting did not seem safe nor did it give enough headroom for the blocks.

After careful consideration it was decided to go up to the bunker floor for a place to hang the blocks. Referring to Figs. 1 and 2, the large girders, A on the column centers gave a good support and four pieces of 12 in. x 12 in. long leaf yellow pine, B, 32 ft. long, were placed, on about 30 ft. centers. Then additional supports C were placed under

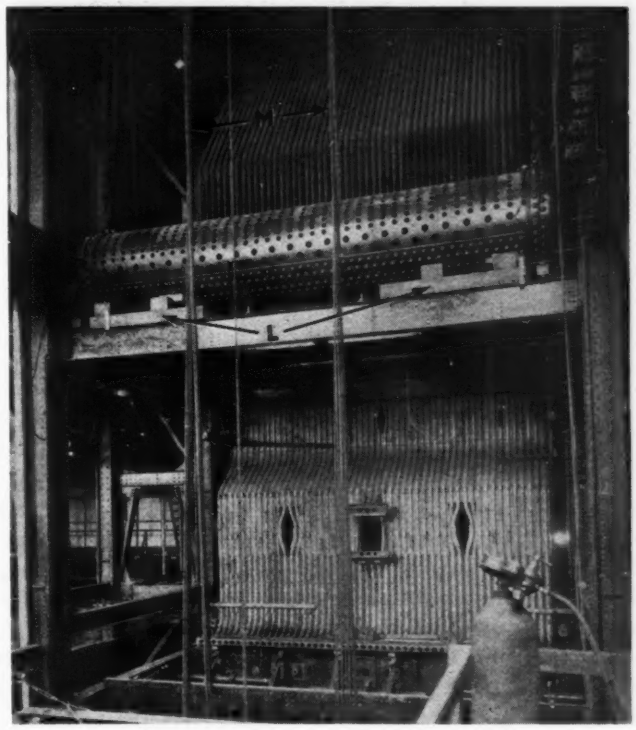


Fig. 3—Placing mud drum. The boiler and furnace tubes shown are those of the opposite unit.

these pieces at the points where the blocks were lashed. The blocks used for hoisting the drums were five and six sheave blocks, using ⅞ in. dia. plough steel cable. The cable in turn was led through the blocks to a 125 hp. double drum electric hoist. The line pull was figured at 12,000 lb. Two sets of blocks were used on each boiler drum as this gave very good control for tilting the drums to clear the building steel while hoisting.

The front 54 in. dia. steam drum D had to be lifted first so that it would be put into position and leave a clear space for raising the upper 48 in. dia. dry steam drum E and also the rear 54 in. dia. mud drum and finally the upper rear 54 in. dia drum. There were several things to be taken into consideration in the raising of the front drum and sliding it forward, and then raising it again and setting it in its saddle. The first was that with the stub column F in place to support the upper 48 in. steam drum, it would not be possible to slide the front drum into position, as this drum was considerably longer than the space between columns. On the other hand, if the supporting steel for the 48 in. dry drum was left out until after the 54 in. front drum was put in place there would be too much time lost before the steel contractor could erect this steel for the dry steam drum, which was scheduled to be hoisted in two days.

On this first unit, all the supporting steel for the upper drum had been erected by the time the first

drum was ready to be raised. Therefore the stub columns F were in the way of moving the drum forward. To overcome this difficulty, cables with turnbuckles were fastened around the ends of the supporting steel and fastened to some steel higher

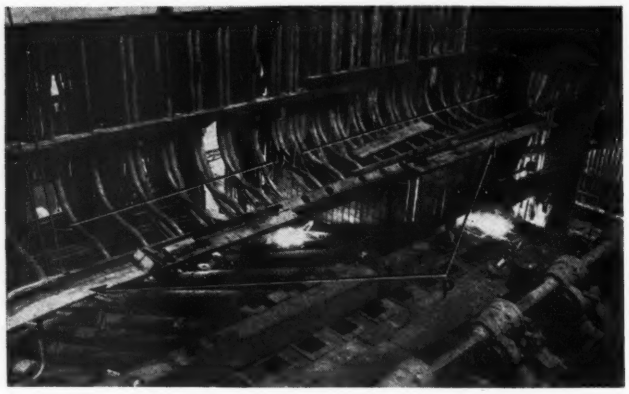


Fig. 4—Arrangement for holding lower front wall header in position.

up. The load was then off the stub column and by cutting out some rivets the columns were removed. This gave us just about enough room for the drum to pass under the girder beam H. On all other units, the columns were left loose and acted as temporary supports until steel was cabled for the drum to pass. These columns were then put back into place and the dry drum could be raised on scheduled time.

In sliding the 54 in. drum forward it was necessary to put a 2 in. x 2 in. square steel bar on top of the girders to allow the drums to clear the rivet heads. Chain blocks were used to pull the drum approximately into position. These blocks were lashed to the front building columns. With the drum past the stub columns, the next move was to get it up into its saddle. This was accomplished by leaving the lashing for the blocks on the drum when it was moved forward. The large lifting blocks were brought over to the other side of the dry-drum supporting girder H and fastened to the drum. Before lifting, 12 in. x 12 in. timbers K were lashed in a vertical position to the stub columns, and corrugated iron J was fastened to the bunker steel as shown in Fig. 2, to allow cable to pass under without damage. A lift was then made with the drum riding against the timbers fastened to the stub columns and when high enough the saddles were slipped under, blocked, and the drum let down into place.

After the front drum D was in place, the dry drum E was lifted next as shown in Fig. 2, (front drum is barely discernible in position immediately behind and below the dry drum). This still left room for the cables and blocks to pass and raise the lower 54 in. drum and finally the rear 54 in. saturated steam drum. The mud drum was raised with the hoist, a little higher than its final position, and by the use of a chain block on the building columns in the rear and fastened to the end of the drums, it was twisted and pulled back between the columns and let down in the approximate location. The large sheave blocks were then removed and the drum finally located by raising with large chain blocks fastened to the floor steel above and let down and wedged in timbers L as shown in Fig. 3. This also shows cables M hanging loose ready to be attached for raising rear 54 in. saturated steam drum.

The rear 54 in. steam drum being the last one to be raised, the equipment which included timber, sheave blocks, cables, etc., was moved on to the next unit. The hoist engine, however, was kept in the one place and lead blocks changed to suit the different units. Three drums were raised per week and, in one instance, four.

The next item to give concern was the lower five sided front wall header, which had to be held in position for tubing. This is a floating header and was held in its proper elevation by steel cables and turnbuckles N, Fig. 4 but due to the traveling coal lorry, no cables could be stretched to the building columns opposite to keep header the proper distance from the center line of column. This header has "T" iron guides O, Fig. 5 welded onto it to hold it when finally bolted up to the stoker steel, and, over these guides, pieces of scrap structural steel P, Fig. 4 were fitted extending out beyond the columns. This steel then rested on timbers Q and held the header in the desired location as shown in the photograph.

On the last four units, it was much easier to hold these headers as the stoker steel was in place and

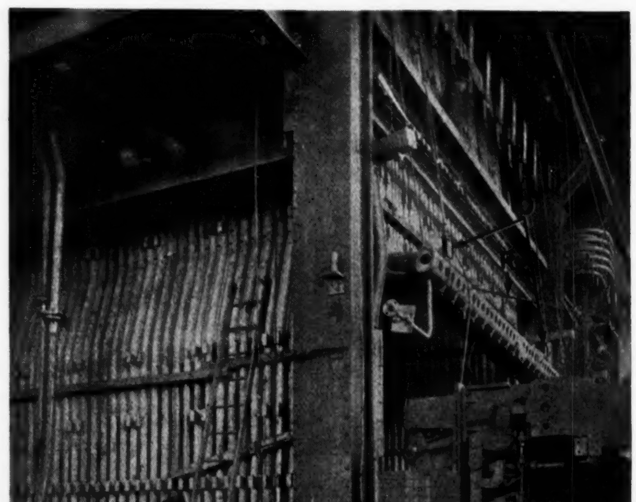


Fig. 5—Side view of unit showing lower front wall header in position.

the header could be hung in slings as shown in Fig. 5, and held away from the columns by cables R.

The next item that gave considerable trouble was the erection of the superheaters. The headers were hoisted and put into position on their saddles quite

readily, but to find a quick and satisfactory way of getting the elements into place was quite different.

At the request of the Superheater Company, every other tube, as far as possible, was left out of the front wall, as shown in Fig. 4, to allow the elements to swing out and up and then be brought back between the boiler tubes after being bolted to the headers above. The idea was to lift one element at a time and then, when the unit (three elements) was raised, to bolt bearings for it in place by reaching between the tubes. The elements were hoisted by cable from an electric hoist. This proved to be a slow, unsatisfactory and expensive method of working. After considerable experimenting, it was found that by using chain blocks, back and front, the whole unit (three elements) could be lifted and pulled back through the tubes without leaving out any of the front wall furnace tubes. To do this the ends of the superheater tubes had to be drawn into line by means of a 3/8 in. flexible tiller rope entwined between them.

The superheater elements were shipped to the job in bundles and unloaded from the lighters onto the dock. The bundles had to be broken open and elements carried into the boiler room singly and units made up one at a time, then hoisted. One gang was used to make up the units on the basement floor and another gang to hoist them into place.

The superheater units were made up right and left hand and at the start of the job, the units were started at one end of the boiler and the same gangs worked clear across. However, this method was changed and the bundles of tubes were brought into the boiler house, then broken and all right hand and left hand units made up and each piled in a separate group on the basement floor. Then one gang was started hoisting at one end of the boiler and another at the center. This cut the time and cost considerably.

The job to date has moved along very smoothly, and, from present indications, it would appear that the equipment will be ready for operation well within the scheduled dates.

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Northern Equipment Company, Erie, Pa., announced the appointment of the Hopton Company, 404 Denison Building, Syracuse, N. Y., as representative for Copes Feed Water Regulators, Differential Pressure Control Valves, Pump Governors, Condensate Drainage Controls and allied equipment.

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Ralph N. Robertson, formerly with the Blaw-Knox Company, Pittsburgh, Pa., has been appointed chief engineer of the Atwood Bradshaw Corporation of the same city.

British Institute of Metals Postpones American Meeting

The 1932 American meeting which was to have been held in the United States and Canada next fall, has been postponed. This move was due to the disturbed economic and financial conditions that prevail in Europe and America. The meeting had been planned with the close cooperation as prospective hosts of the American Institute of Mining and Metallurgical Engineers. An announcement will shortly be made regarding the institute's place of meeting next autumn.

•

General Refractories Company, Philadelphia, Pa., announce the following appointments, made at a meeting of the board of directors: F. L. McManus, Vice-President in charge of Traffic; D. M. Thorpe, Vice-President in charge of Sales; L. Tschirky, Vice-President and Assistant to President.

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The American Society for Testing Materials has issued a 1931 index to A.S.T.M. Standards and Tentative Standards, which is available without charge at society headquarters, 1315 Spruce Street, Philadelphia, Pa.

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Bailey Meter Company, 1050 Ivanhoe Road, Cleveland, Ohio, announce the appointment of W. J. Reeder as Manager of its St. Louis Branch Office. This appointment fills the vacancy made by the recent death of Mr. C. J. Pendergast.

For the past seven years, Mr. Reeder has been connected with the Chicago Branch Office of the Bailey Meter Company where he has had a wide experience in the solution of metering, controlling and regulating problems.

Mr. Reeder will be assisted by Mr. J. R. Buss, who has been located in the St. Louis district for the past four years. Their headquarters will be at 127 Waterman Building, 457 North Kingshighway—Telephone Delmar 4770.

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Lincoln Arc Welding Competition. Announcement of the winners of the Second Lincoln Arc Welding Prize Competition will be made within a few weeks, according to A. F. Davis, Vice President, The Lincoln Electric Company. Judging of the papers was begun on November 1 by the jury of award headed by Dr. E. E. Dreese, chairman of the electrical engineering department of Ohio State University. This competition, which will award $17,500 for the best papers on redesign for arc welded construction, closed October 1, 1931 with four times as many papers entered as in the first contest sponsored by The Lincoln Electric Company of Cleveland in 1927.

History and Developments in the Art of Welding Ferrous Metals

PART I

By A. J. MOSES,
Superintendent, Hedges-Walsh-Weidner Co.
Chattanooga, Tenn.

Due to the remarkable progress that has taken place in the past few years in the art and practice of welding, and especially because of the recent extension of this art to the fabrication of high-pressure vessels, there has been increasing evidence of a lively interest in the broader aspects of this subject. In order to provide a better background for the appreciation of this development, COMBUSTION is presenting a series of several articles in which the history and development of the welding art to date will be reviewed, and the various methods now in use described in detail. The author of this series is an authority on the subject, especially in the field of fusion welding, and has made extensive studies in the history of the art. Part I generally reviews the history of welding and begins the discussion of the Forge Welding processes. The illustrations shown are reproduced from Forging-Stamping-Heat Treating, January, 1927, issue.

HISTORY does not record the discovery of the art of welding. Like the discovery of, and the use of many of the metals, it is probably older than history. With the exception of platinum and gold, iron was the only weldable metal until very recent times. While museums contain many examples of ancient soldering, there are few if any specimens of early welding. This is in no wise a proof that soldering antedates welding. Soldering was early applied to metals which resist the wasting action of time, while welding was mostly applied to iron which is a perishable metal. Many wonderful examples of the ancient jewelers' art of soldering have been found in excavations and in explorations of the pyramids. While we have positive proof that iron was in use at that time, any examples of the welders' art has long since rusted away. The wrought iron column at Delhi is 16 in. in diameter and extends 22 ft. above ground. It is made up of welded sections, but in a sense, this column is modern. The use of iron and the knowledge of welding was several thousand years old at the time of the erection of this column which has been placed at about the fourth century A.D. Undoubtedly the discovery of the weldable quality of iron was coincident with or shortly succeeded the discovery and first use of that metal. There is no definite historical data but we know that the early history of welding is intimately related to the early history of iron.

The date of the discovery of the metal iron is entirely problematical. On this basis it is assumed that its use postdates that of those metals which are found in nature in an almost pure state such as gold and copper. Since iron, excepting in meteorites, rarely occurs in nature in the free state, its first production must have been the result of some fortuity. It is most likely that this occurred much later than the accidental finding of gold, copper and the copper-tin alloy, bronze. The evidence of history indicates this. As far back as 4000 B.C., rock carvings in ancient Egypt depict placer mining operations for gold. A wrought iron wedge was found in the Great Pyramid of Gizeh, which is placed at about 2900 B.C. The Bible first mentions iron in the fourth chapter of Genesis or only a few generations after Adam but there is no means of affixing a definite date to this. The book of Genesis is supposed to have been written by Moses about the thirteenth century B.C. There is much evidence that the Babylonians and Assyrians were well acquainted with the use of iron, probably as far back as the Sumerian City Kingdoms or about 5000 B.C. One tradition is that iron was first discovered in Greece during the accidental burning of a wood. But later evidence discloses that knowledge of this metal was well advanced in Asia Minor long before the dawn of civilization in Crete. Also there is evidence of the early production of iron in China, India and Borneo. It was being produced in Great Britain in 55 B.C. at the time of the Roman invasion, also in Spain and Scandinavia.

Cortez and Pizzaro did not find the Aztecs or Peruvians possessed with any knowledge of iron, but in modern times iron-making tribes have been discovered in the interior of Africa.

This early, widespread knowledge of iron indicates that its introduction was the result of separate and distinct discoveries in various parts of the world in the early dawn of history. Or else, it is an art handed down and disseminated from pre-historic times. Probably in a measure both of these assumptions are true. The Biblical story that iron was known to the seventh generation from Adam is entirely logical. This knowledge could have been spread to nearly all parts of the world by the Nomads whose extensive migrations are attested by the presence of the Indians in the Americas.

The manner of the discovery of iron is as problematical as the date. It may have been a meteorite that first attracted some one's attention. Even so, such a discovery was not of major importance. It was the seemingly accidental reduction of iron from one of its ores that first gave to man control over this most useful of all metals. This may have occurred from a variety of circumstances. Of these the conjectures of David Mushet in his "Papers on Iron and Steel," appear most plausible. He surmises that the discovery was made in connection with the conversion of wood into charcoal, which operation is undoubtedly almost as old as man himself. Given the presence of heated charcoal, a mud covering magnetite, a period of neglect wherein a lump of ore would accidentally drop into the burning pile during the existence of a strong draft, he rightly reasons that the discovery was unavoidable. Regardless of the details it is certain that the reduction of iron was first accomplished under conditions somewhat similar to the above, that is, by the accidental bringing together of iron ore and heated carbon. The proof of this is, that this most versatile of all the metals, was first known only in such a form as would be derived from such methods of reduction. It is certain that iron in a completely fused state was unknown to the ancients. In fact cast iron is a product of an almost modern discovery, being introduced during the fourteenth century.

The discovery of welding may have been made in connection with the use of the metal, gold. For gold in a pure state is the most weldable of all the metals. In fact in the absence of certain impurities it can be welded at any temperature. In the beating out of gold leaf care must be taken to prevent welding when several layers are pounded together. This is avoided by placing the gold strip between the thin outside membrane of the intestines of cattle. The massive objects and chains fabricated of this metal by the ancients prove conclusively that their weldable quality was well known. The unearthing of gold coins and other objects of remarkable purity, also shows that the goldsmiths of very early times were very skillful in the removal of impurities generally contained in the raw state. But the ancient art of soldering gold has received more prominence than that of welding. As far back as 5000 years the Egyptians were producing a form of granulated gold jewelry which demonstrates a process of soldering, which for minuteness and delicacy of manipulation is beyond the skill or patience of modern workmanship.

Whatever man may have first known concerning the art of welding gold, it was his application of this art to iron which has attained the most importance. This application could not have been later than the earliest purposeful production of this metal in usable quantities. In fact welding had a vital part in the earliest method of producing iron. The pre-historic smelter must perforce have availed himself of the weldable quality of iron in obtaining usable masses of the metal from the rather small lumps which were the product of his rather crude reduction process. History affords some rather reliable clues as to this early method. Unquestionably the reduction was accomplished in open air furnaces wherein the ore was reduced by heated charcoal, into small plastic masses of low carbon iron saturated with slag and other impurities. At the expiration of the reduction period the white hot balls of metal were gathered together and hammered. By hammering much of the slag was eliminated, the small lumps were welded into a somewhat homogeneous whole, and some desired shape given the substance. This crude metal produced directly from the ore without fusion, was the forerunner of modern puddled or wrought iron. Subsequent shaping would have required reheating, and so it is reasonable to presume that the early iron workers soon acquired the art of hammer-welding separate pieces together.

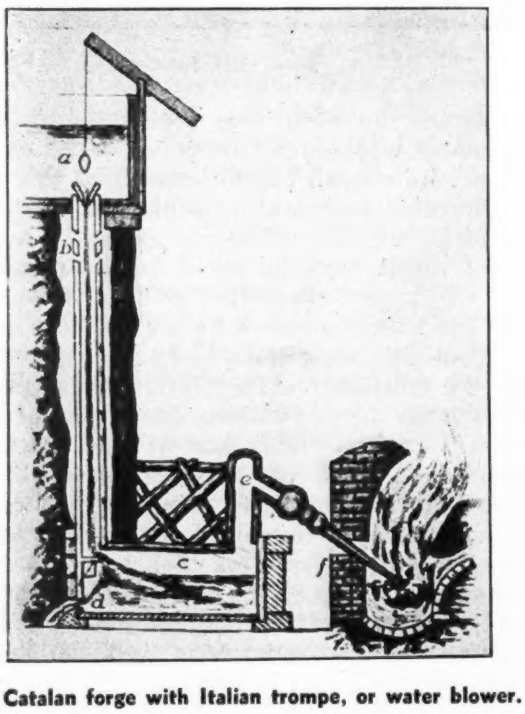
An early blast furnace.

We can recognize in the early production of iron a prototype of the later production of platinum. Platinum was discovered about two centuries ago. Its first production was analogous to that of iron. Both were discovered and produced before such temperatures as are required for the complete fusion of these metals were obtainable. Both metals are highly weldable below their fusion points. In both, welding played an important part in their early production. From historical clues, this analogy, the probabilities of the matter and the trend

of development, it is reasonable to presume that man first used and recognized the welding properties of iron in the very inception of that industry.

This early method of joining iron in the unfused state has been handed down to us in that form which we know as smithwelding or forge-welding. While some improvements have been made over the first crude attempts, the smiths early attained a high degree of skill in this art, as judged by the quality of metal produced and the less exacting requirements of the time. For centuries this was the only method of welding iron known to man. For centuries no material improvements were made in this method other than in the matter of fluxing materials. But the key to the function of the fluxing agent was present in the beginning in the presence of the slag which permeated the mass of low carbon iron. This together with man's early knowledge of soldering lead him in the search for and the selection of a satisfactory fluxing material.

As with welding, no marked improvements were made in the production of iron and steel up to the Middle Ages. There is very little information regarding the first conversion of iron into steel, or the production of steel direct from the ore. Steel is mentioned in the second book of Samuel which is placed at about 1000 B.C. History recounts that Porus made a present of forty pounds of Indian Steel to Alexander the Great. This was about the year 330 B.C. The size of this gift proves that at that date steel was a valuable and exceedingly rare article. Until the middle of the nineteenth century the only steel known was of the high carbon variety. The first steel produced was probably due to an accidental leaving of low carbon malleable iron in contact with a bed of hot charcoal for several days, resulting in a kind of cementation steel. Until the middle of the eighteenth century, practically all steel was made by the cementation process. In 1750, Huntsville, an English smith, is credited with having introduced crucible steel, although there is evidence that the Wootz steel of India and the famous blades of Damascus and Toledo, were a product of the crucible process. Of these famous blades it is said that the twisting and welding of two grades of steel gave them their cutting properties and contributed a beautiful water mark pattern.



A Catalan forge with Italian trompe, or water blower.

In the production of iron, the Catalan Forge, introduced in Spain at an unknown date, by the addition of blast gave some improvements in quality and quantity over the original open air furnaces. About 1350, the Germans produced the first cast iron. They developed a higher stack type of blast furnace in which, with the aid of an excess of carbon, they were able to produce iron in its most fusible state. Coke was first successfully substituted for charcoal in the reduction of iron in 1713 by Darby in England. The first malleable cast iron was produced by Reaumur, a Frenchman, in 1722. Following the invention of the steam engine in 1770, higher and more constant blasts were available. In 1784, the first rolling mill was brought out by Cort. Also about this time the puddling method of making wrought iron was developed. In 1830, Neilson made application of the hot blast in pig iron production. But all of these improvements and new processes are insignificant as compared to the Bessemer-Kelly process of manufacturing low carbon steel, introduced about the middle of the last century. This was followed shortly by the equally important Siemens-Martin open-hearth process which has since outstripped the Bessemer method in quantity of production. These momentous innovations ushered in a new era which we are beginning to call the Steel Age.

Status of Welding Art at the Beginning of the Extensive Use of Steel.

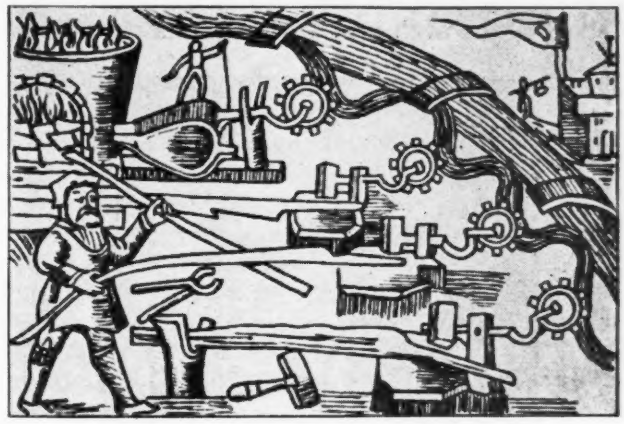
At the beginning of this new age, the art of welding had been stagnant for centuries. It had lagged in attaining its proper sphere and, despite recent development, has not yet reached the status to which it is entitled. The one known process of welding could not meet the varied problems created by the enormous increase in the use of steel. Many new processes were discovered but these were slow in developing and in obtaining recognition. Engineers in general have been interested in what they considered more important problems. They have been extremely slow in appreciating the possibilities of either the old or new processes and have, as a matter of course, preferred the older form where applicable or the wasteful method of riveting. Engineers and designers, however, are not entirely to blame for their lack of interest. The promoters of the various processes of welding have been guilty of over-advertisement of the true worth of their product. There has been an intentional tendency to play up those qualities in which their product excelled and to suppress those qualities in which it was sadly lacking. This has been the cause of many misapplications and consequent

distrust. But undoubtedly that which has most deterred the universal acceptance of welding has been the lack of a standardized and reliable method of testing. In the fabrication of metal structures, welding is in a sense a final operation and permits of no second guessing. A reliable yardstick for measuring the quality of welds has only been available to engineers and architects within the past few years. But as yet this new yardstick is not so flexible as to be applicable to all types and forms of welding application. However, despite many setbacks, the art of welding has continuously made progress during the last half century and remarkable progress during the last decade.

Welding as applied to metals may be defined as the art of joining two or more pieces into a consolidated whole. To differentiate welding from soldering, it may be said that the former implies that the juncture is effected without the addition of a third extraneous metal. The joining of two dissimilar metals is also generally referred to as welding. In such cases the juncture is an alloy of the two. Since alloys possess many characteristics entirely distinct from their constituents, the latter operation might rightly be referred to as soldering. As we have noted, from a promising start, man's progress in the welding art has been rather slow. He has often made, and undoubtedly continues to make, erroneous deductions and to give fictitious values regarding this progress. This is due to a very limited knowledge which misinterprets phenomena, and to imperfections in procedures and in methods of measuring results. In order to gain respect and confidence the definition of welding should be standardized. In the past the term, "a good weld," conveyed no exact information. It might convey that it is good in the light of a limited experience in a specific field of application. It could be judged good, according to unreliable methods of testing. Or it could be a satisfactory soldering job sufficient for the occasion. A good weld comprises the joining of two or more pieces of similar metal into a consolidated and homogeneous whole, all parts of which display physical and chemical characteristics equivalent to and within the tolerances obtainable in the manufacture of the base material. Only in so far as it meets these requirements, can it be called good. At the present time the designer has various welding processes to choose from, with some definite knowledge concerning the advantages and limitations of each, and in some branches of application, a standardized code which helps to insure quality workmanship. These processes will now be discussed.

Forge-Welding Processes.

Forge-welding holds an honorable position because of its history and usefulness in the past. It consists of three operations: (1) preparation of the pieces to be joined; (2) heating and fluxing; (3) joining and hammering the juncture of the two pieces. In the preparation, the pieces to be joined are usually upset and scarfed to form a lap weld, although butt, jump and split joints are sometimes used. Heating may be accomplished with charcoal, coal, coke, gas, oil or electricity, care being taken to avoid an oxidizing condition. The pieces are first heated to a red heat then the areas of juncture are fluxed with silica sand, borax or other fluxing substances to remove oxide scale and to preserve clean surfaces. The pieces are then brought to a white heat if the metal is wrought



A Swedish application of the water wheel for operating forge hammers.

iron or low carbon steel. At that temperature, these metals become very plastic, and the flux, a liquid coating over the area to be joined. Having attained the proper welding temperature the pieces are fitted together and rapidly hammered, working from the center of the juncture area outward so as to force out all slag and flux. The parent metals adjacent to the weld juncture are then hammered in order to break up any large grain structure incident to the high heat subjection.

The above is a rough description of how forge-welding in its simplest form has been carried out by blacksmiths for centuries. Forge-welding today, may be disguised in various shapes and forms, but nevertheless it has undergone no radical changes in principles or process. New methods of preparation have been worked out in the search for the best methods for specific applications. New heating agents have been adopted in the choice for suitability to specific conditions and class of work. Newer methods of applying pressure have been substituted for the hammer and sledge wielded by the blacksmith. Thermal stress relieving and annealing have been substituted for the unreliable hammer refining by the smith. Among the many forms of forge-welding as now practiced are some which are of sufficient importance to justify separate and detailed discussion. Of these, hammer and roll welding, resistance and flash welding, will be taken up in order, and are not necessarily contemplated in the following discussion of the advantages and disadvantages of forge-welding.

More success has been obtained by this method of welding in connection with wrought or puddled iron, although it is applicable to the milder carbon and some of the alloy steels. This is true because this material, being almost pure iron, becomes plastic through a wide range of temperatures below

its high fusion point. Therefore it is solid but plastic at temperatures which liquify the oxides, slags and other impurities which would prevent perfect cohesion of clean molecules. Being in the liquid state, these impurities are squeezed out during the hammering operation. Also, wrought iron is somewhat self fluxing because of the fibrous slag included in that material. Being very low in carbon, the metal adjacent to the weld is not so adversely affected by the high heat and responds better to the

Early form of belly helve hammer, from Agricola's "De Re Metallica." The water was not only used for power, but also for heat treating purposes.

hammering or refining operation than do the more temperamental metals and alloys. But proper heat treatment of many of these metals relieves the stresses and refines the grain structure of both the adjacent material and the welded juncture, and hence discounts whatever advantages the forge welding of wrought iron may hold in this respect.

Forge welding is applicable to only a few of the metals and alloys. Until the introduction of the fusion process many of these were considered unweldable. In that field of materials wherein it attains its greatest usefulness, it has narrow limits as regards sizes and shapes. In this type of welding, the skill of the operator is the most important factor controlling the quality of the joint. In the hands of the most skillful smiths the welding of heavy sections and awkward shapes is entirely unreliable. Under ideal conditions the best forge welds of low carbon iron and steel will show about 90 per cent of the tensile strength of the base metal and only about 30 per cent of its ductility. The latter figure can be increased considerably by annealing. The defects usually encountered in this type of welding are overheating or imperfect union due to entrapped slag or iron oxide. The first of these, if the metal is not actually burnt can be corrected by subsequent heat treating. The latter, excepting in the form of surface seams, cannot be detected by ordinary means of inspection, either during or after the completion of the operation. The knowledge that imperfect unions are frequently encountered in this class of welding, and that these imperfections are often extensive, has tended to restrict forge welding to an unimportant class of work. Notwithstanding this knowledge forge welding has an unenviable reputation as the result of a long list of weld failures that have caused enormous property damage and considerable loss of life. However, in justice to this time-honored art, it might be added that by far the majority of these failures have occurred in modern times, and are due to a disregarding of its limitations and because of the lack of a thoroughly reliable, non-destructive test.

Hammer-welding: This is the modern term applied to a specific development of the old smith-welding process. In this method, which has attained a wide field, the pressure required to effect the juncture is supplied in the rapid blows of a steam or air hammer. Thus the welding of much heavier sections is made possible. One of the most important applications of this method is the hammer-welding of the seams of cylindrical vessels such as boiler drums, furnaces or other pressure containers. Welds by this method are usually of the lap joint type. The welding of pressure vessels differs from the ordinary in that it is impractical to carry the work to and fro between the forge and the hammer. In this procedure, everything must be done to facilitate a rapid completion of the hammering operation as soon as the work has reached the proper temperature. For this reason the cylindrical shell, with joint edges scarfed and lapped, is slipped over a stake anvil underneath the hammer in position for this operation, or in such a manner that it can be quickly rotated or shifted into working position. The forge or heating apparatus in this case, is brought to the work. The heating agent is usually gas. The work progresses in steps. A short section of the lapped edges is brought to a uniform welding temperature and then moved underneath the hammer and forge welded together.

One of the earliest uses of the mechanical hammer was in the shaping, refining and welding of the pasty product of the reduction furnace. Its use in the welding of sections too heavy for the blacksmiths' sledge was a logical development. Such welding has long been in use in the fabrication of cylindrical shells. The welding of the longitudinal seams of large flues and furnaces for Scotch marine boilers is a common practice in England, Europe and America. In such applications, this is not a risky proposition inasmuch as these flues and furnaces are subjected to external pressure only. Also many of the early boiler shells were fabricated in this manner. Up to as late as 1890, and possibly later, hammer-welded longi-

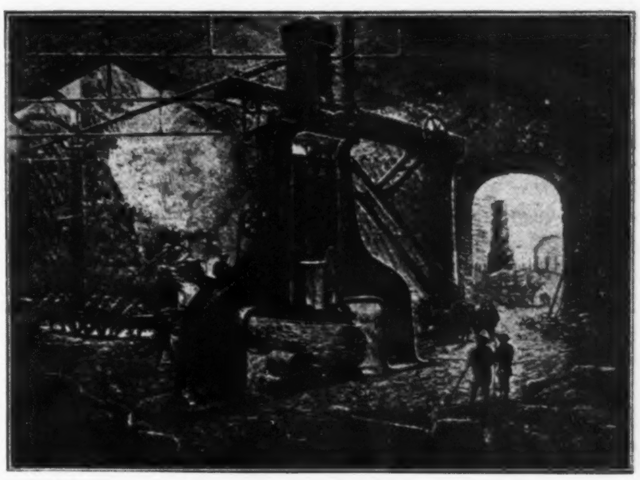
tudinal seams and riveted girth seams were being used by several firms in Great Britain in the manufacture of boiler shells. But up until that time, wrought iron was the material used in such construction, and plate thicknesses were much less than those encountered today. In the early stages of this particular application, coke was used in the heating operation. The forge was placed directly under the hammer. The shell, with the seam downward was placed on this forge in such a manner that the heated section could be rapidly rotated to a vertical position between the hammer and stake anvil. Many improvements have been made over this method of heating, water gas being now extensively used. Aided by other improvements in recent years, this method of fabrication has been pushed to its apparent limits. Pressure vessels of a wall thickness of one and seven-eighths inches, have been so constructed. Such hammer welding of even high pressure vessels has received a great deal of attention in Germany and has attained considerable usage. In America it has gained some degree of popularity but in the last few years it has given ground to the more flexible and reliable methods of welding.

Hammer-welding has been more successful with wrought iron and low carbon steel. In light section welds, it produces joints about 10 per cent stronger than can be obtained from the manual process. Some rather exhaustive tests of hammer-welded pressure vessels were made in Germany several years back, by the firm of Messrs. Thyssen & Co. The test drums were made of 1⅞ in. thickness, low carbon steel of about 50,000 lb. per sq. in. tensile strength. Published data discloses a tensile strength for the welded juncture only slightly less than that of the plate material. But the ductility of the joint was considerably less than that of the plate. An average of annealed samples gave 17.25 per cent elongation in 8 in. for the weld as against 29 per cent for the plate.

The use of the power hammer in this system of forge-welding does not widen its field of application as regards the various metals and alloys. It does increase its scope with respect to size and shapes. It also tends to lessen the importance of individual skill in obtaining sound welds. The accomplishments of the long experienced firm of Messrs. Thyssen & Co. are probably representative of the most efficient weld joints now being made by this process. Results of their tests prove a somewhat reliable weld, but one that is not the equal of the plate material in all of its physical properties. The selection of low carbon steel of low tensile strength is followed not entirely because it favors successful hammer-welding, but also because of a realization that ductility is of prime importance in the fabrication of such vessels as boiler drums. However the joints of these vessels show a sacrifice of some 40 per cent of the ductility of the original plate as evidenced by the lower elongation results. This loss in ductility at the joint is probably not due to any changes of grain structure in adjacent plate material, because proper heating, working and subsequent annealing practically assures a satisfactory result in this respect. It is most likely due to the presence of impurities and a lack of perfect cohesion along the line of juncture. All of the samples failed at or near the joint and probably all elongation was localized to that vicinity. The fact that such imperfections did not materially lower the tensile strength of the joint can be explained by the fact that the direction of the tensile pull was not normal to the scarfed line of juncture.

Such would appear to be the expected nature of any defects encountered in hammer-welding. Also the danger of local overheating or actual burning in the attempt to heat heavy sections uniformly to a welding temperature, is ever present. But proper preparation of the plate edges, careful heating and subsequent annealing can be relied upon to minimize this danger. The obstacles to overcome, in producing heavy section hammer-welds which are truly equal to the plate material when tested normal to the line of juncture, would appear insurmountable. The total elimination of slag or oxide impurities is well nigh impossible. In heavy section work these have a comparatively long distance to travel to reach the surface, and hence are apt to be entrapped by the jaw-like closing of the seam, mainly depended upon to effect their expulsion. There is no fluid metal along the joint which, in other processes, floats the slag to the surface.

Also such defects as are likely to occur internally with this method of welding, are difficult of detection even when subjected to X-ray examination. The forging operation insures a closeness of contact between the plate edges, if not perfect cohe-



First steam hammer in full work, from a painting by James Nasmyth.

sion. Hence any intervening impurities will be worked microscopically thin. Etched, polished samples of such welds show clearly the thin line of the seam. It is extremely doubtful whether the X-ray would detect such faults although they may constitute a dangerous alignment. To be at all efficient, the incident X-rays should be parallel to the scarfed seam. Such radiography, when deal-

ing with heavy plate is of doubtful technique. Surface seams can be deducted, and although granting the possibility of exposing internal flaws, recourse must be taken to other methods of welding if any repairs are to be undertaken. There is abundant evidence that really perfect welding cannot be obtained continuously on first attempts, by any process. Economy dictates and results prove that repairs can be successfully made in the fabrication stage. If this right is available, then, in the search for that rarity, a perfect weld, no method of welding can be accorded merit over the method of shop repairing. Hammer-welding as well as all other processes, suffer in comparison with the ideal joint. Nevertheless there is a broad field of usefulness in which the product of this method is amply sufficient. This field extends from the ordinary blacksmith jobs of light and heavy sections, to the fabrication of vessels subject to external pressures and moderate internal pressures. It is in the fabrication of high pressure vessels, where perfection is desired, that in America at least, this method is being supplanted by more reliable, economical and adaptable processes.

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The Centrale Noord 11 Station at Amsterdam

(Continued from page 32)

regard to huge scale water pumping and civil engineering, especially in the way of dykes and other protective measures against the encroachment of the sea, but also in connection with coal mining and the use of electricity. As regards the latter, one feature is the increasing use of electricity in Holland for domestic purposes. Dr. Lulofs, for example, points out that in 1930 the total amount of electricity supplied by the Amsterdam Corporation was 262,000,000 kw.-hr. for a population of approximately 760,000 inhabitants, that is 345 kw.-hr. per head per annum. This of course to American readers may seem very small, but it must be remembered that Holland is largely an agricultural country, and a considerable proportion of the consumption, therefore, has naturally to be in the domestic field. Incidentally it may be stated that one of the results of the World War in Holland was to practically kill gas and oil for lighting, due to the complications involved and the difficulties of exporting and importing material from either Germany or the Allies, together with the fact that a considerable proportion of the Dutch able-bodied men had to be more or less permanently mobilized in case of invasion. Consequently, today, electric lighting is almost universal throughout Holland, and the domestic use of electricity for cooking and heating has made great strides, including particularly the heating of water, a large proportion of the domestic consumers being supplied on the one-tariff system, that is an equal rate for electricity irrespective of the use.

Another interesting feature in this connection, in Amsterdam, is the extent to which domestic electric appliances can be obtained on the hire-system, another practice which deserves to become more general. Amsterdam is fortunate also in having its supply of electricity under one control, very different from London for example, with its multiplicity of authorities. The latter, however, is due to the fact that so far as the use of electricity is concerned, London is a very ancient city, the first electricity station in the history of the world having been built by Colonel Crompton at Kensington shortly after 1880.

It is well known of course that the "Low Countries," a name applied for many centuries to Belgium and Holland, have been one of the leading industrial centers of the world for over 1100 years, especially as regards iron and steel production. In this connection, it is interesting to note that the blast furnace was invented at Namur, Belgium, in 1320 A.D. While most of the iron and steel works and collieries in this area, along with a host of accessory industries, are in Belgium, it is remarkable that Holland has continued well to the front in the different sections of engineering already mentioned, just as she has steadfastly maintained her position as one of the prominent seafaring nations.

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Sheldon, Morse, Hutchins & Easton

A new type of service organization, to facilitate the marketing of industrial products, has been formed by Dr. H. H. Sheldon, H. A. Morse, L. W. Hutchins, and Dr. W. H. Easton, all well known in many branches of industry, engineering and science. The company, with offices at 191 West 10th Street, New York City, will be known as Sheldon, Morse, Hutchins & Easton.

The group will give special attention to economic problems in connection with scientific research, by assisting manufacturers to determine the applications and markets for products, estimate the amount of research necessary, make surveys of competition and patents, and plan research work to meet market conditions. The company also plans to furnish complete sales research, advertising and publicity service in the field of chemicals, electrical equipment, building materials, industrial and marine supplies and machinery, scientific apparatus, and other lines.

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Oxwelded Piping Exhibit. At the International Heating and Ventilating Exposition, Cleveland, Ohio, January 25-29, The Linde Air Products Company, New York, portrayed in their exhibit the wide variety of applications of oxyacetylene welding and cutting, showing typical welded specimens of various kinds of piping. The exhibit was in charge of Mr. T. Schwartz.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Science in Action

By Edward R. Weidlein and William A. Hamor

THE authors of this book, who have in their charge the direction of the Mellon Institute of Industrial Research at Pittsburgh, have managed throughout the book to live up to the purpose and scope which they outline for it in their preface. It presents "in clear language the methods and accomplishments of industrial research, that is, scientific investigation as applied to the production and merchandising problems of various branches of manufacture, and to the promotion of human welfare, especially in the United States."

The book begins with a review of the groundwork of industrial research, then a review of industrial research as it is now being carried on in the United States. They discuss its present status in this country and the types of laboratories in which such research is being accomplished.

For the reader who wants to be informed about industrial research statistics in the United States there are data which tells him that this country spends $155,000,000 a year for the operating expenses of 1,600 industrial research laboratories; 800 ounces of silver can be recovered from one million feet of waste movie film; in brick-making a machine now makes 40,000 bricks an hour, whereas it once took one man eight hours to make 450 bricks, and a host of other interesting and sometimes startling figures and facts.

This book can safely be recommended, especially to industrial leaders and workers in science, for it will lead to better understanding and appreciation on both sides. To the lay reader who is interested in the significance of science in modern life it offers an abundance of information authoritatively presented.

This book, size 6 x 9 inches, contains 310 pages including 32 illustrations. Price $3.00.

A. S. M. E. Boiler Construction Code

(1931 Combined Edition)

THIS 1931 Combined Edition contains the latest specifications as formulated by the A.S.M.E. Boiler Code Committee covering construction of power, low-pressure heating, locomotive and miniature boilers, also unfired pressure vessels, suggested rules for care of power boilers, rules for inspection and the latest material specifications used in the construction of boilers. There is also a comprehensive index.

Incorporated in this Code are the new rules covering the fusion process of welding which were formulated by the Committee during recent months and were released to the industry in August of last year. This book is bound in green cloth covers and contains 576 pages. Price $5.00.

1931 A. S. T. M. Proceedings

American Society for Testing Materials

PROCEEDINGS of the Thirty-Fourth Annual Meeting held at Chicago, Ill., June 22-26, 1931. Vol. 31. Just issued in two parts, both parts comprising more than 2100 pages.

Part I. Committee Reports. New and Revised Tentative Standards. Revision of Standards. Contains the annual reports of the Society committees on the following subjects: 12 reports on Ferrous Metals; 6 reports on Non-Ferrous Metals; 8 reports covering non-metallic materials. Also included are reports of committees on Preservative Coatings for Structural Materials, Petroleum Products and Lubricants, Road and Paving Materials, Coal and Coke, Timber, Classification of Coals, Bituminous Waterproofing and Roofing Materials, Electrical Insulating Materials, Rubber Products, Textile Materials, Thermometers, Slate, Natural Building Stones. In this part of the Proceedings there are reports of 42 standing and research committees and reports of one joint and two sectional committees. There are 1119 pages in Part I.

Part II. Technical Papers. Contains the technical papers which were given at the annual meeting of the society in June, 1931. The 1931 Proceedings contain many valuable papers on various aspects of fatigue, endurance testing, magnetic analysis, damping capacity and corrosion of metals. A Symposium on Malleable Iron Castings comprises 118 pages. Several of the papers involve tests of concrete and concrete masonry and structures; a Symposium on Weathering Characteristics of Masonry Materials takes up 126 pages. The Abrasion Testing of Rubber is another subject treated, covering 60 pages. The Economic Significance of Specifications for Materials—an important subject—is treated exhaustively and covers 44 pages. Part II also includes papers on modern paving emulsions; the hiding power of white pigments; the photoelectric cryptometer; and others. There is a detailed subject index and an author index. Part II has a total of 1027 pages.

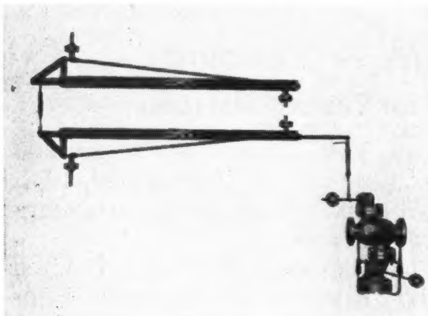
Each part of the proceedings is available at the following prices: paper binding $5.50; cloth binding $6.00; half leather $7.00.

NEW EQUIPMENT

of interest to steam plant Engineers

Feed Water Regulator

A new type of feed water regulator which feeds in accordance with the rate of steam flow and which provides compensation for changes in boiler water level, has been announced by Northern Equipment Co., Erie, Pa. This new regu-



lator, known as the Copes Series Type Regulator, is designed primarily for boilers operating with rapidly fluctuating loads. Boilers carrying swing loads in a central station plant offer a major field for this new regulator. It also has a direct application on boilers in steel mills, cement mills and coke and gas plants.

The Copes Series Type Regulator is actuated by two thermostats connected in series, one above the other. The upper thermostat is influenced by the rate of steam flow in the main steam header; the lower by changes in boiler water level. Movement of either one will operate the control valve.

The upper or steam end of the steam flow thermostat is connected to the main steam header. The lower or water connection is made to a reservoir connected to the steam header at the level of the upper end of the thermostat, and on the trailing side of the steam connection. Steam condensing in the thermostat fills the water connection and the reservoir.

At no load, the steam flow thermostat is filled with water. As the load increases, the difference in pressure between the two connections in the steam header forces the water level down. Steam enters the thermostat, expanding it and opening the feed valve. As the load decreases, the water level in the expansion tube rises, causing the tube to contract and close the feed valve.

A triangular lever is mounted at the end of each thermostat so that it pivots on a fixed point. The levers are connected by a strut, to transmit the force of expansion and contraction of the steam flow thermostat through the level thermostat and thence through a vertical strut to the feed valve in the feed line.

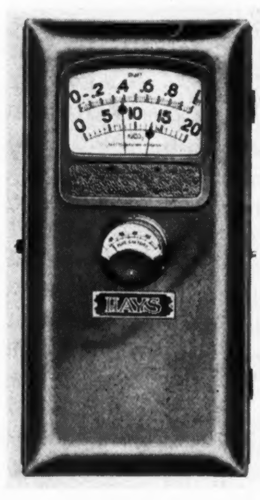
The unit illustrated shows the Series Type Regulator equipped with a Copes Type RG Combined Feed Flow Differential Pressure Control Valve. Further data will be furnished by the manufacturer.

Automatic Combustion Indicator

The new Hays Automatic Combustion Indicator developed by the Hays Corporation, Michigan City, Ind., is designed to provide continuous indications of CO_2 content of flue gases, for CO_2, furnace draft and flue gas temperature, and for CO_2 furnace and uptake draft.

The range of application of this combustion indicator is primarily for use in the steam plants of the larger apartment buildings, laundries, dairies, and in plants where graphic data is not desired or required. It also lends itself to use in the larger steam plants for checking other combustion instruments and, piped to serve two or more boilers alternately, eliminates the drudgery incident to the daily use of hand Orsats.

Water is piped directly to an aspirator, which is an integral part of the machine and passes into the standpipe. The aspirator draws filtered flue gas from the boiler through the measuring burette, and, rising in the standpipe, traps off a measured sample of gas, reduces it to atmospheric pressure, automatically compensates for tempera-



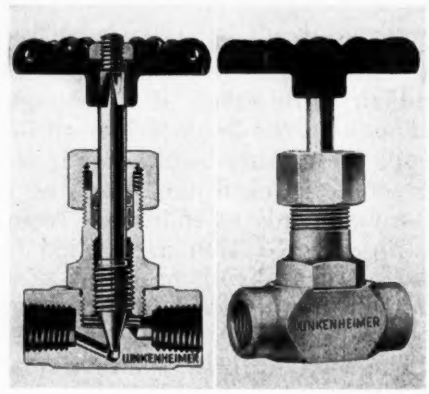
ture changes, then directing this measured sample into an absorption chamber filled with chemically wet steel wool CO_2 is immediately absorbed out. This causes a pressure reduction in a metallic bellows which contracts and thus provides ample torque for operating the indicator. The indicator unit comprises a closed contact tilting mercury switch, a magnetic coil-operated brake and a counterweighted free-floating pointer. The mercury switch is adjusted to make contact a moment before the standpipe syphon discharges, thereby releasing the magnetic brake and permitting the pointer to change its position on the scale providing a change of CO_2 content of the flue gases has occurred. Discharge of the standpipe syphon causes the contact to break. The machine is then ready for another analysis. One analysis is made every 1.9 minutes.

The flue gas temperature unit is a husky dial-type instrument operating on the thermo-electric principle. It is mounted on the door of the CO_2 indicator case as shown in the illustration.

Steel Needle Valves

The Lunkenheimer Company, Cincinnati, Ohio, has developed two new steel needle valves for high pressure gas or liquid service.

These valves are designed to give accurate throttling and regulation at pres-



sures up to 3000 lb. at 150 deg. fahr. The construction is exceptionally heavy with extra long pipe threads. They are used extensively on orifice meters for measuring gas and on other high pressure instrument lines.

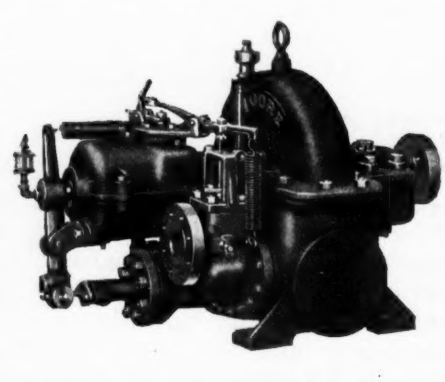
The valves are identical in design, with steel body, hub, stem, stuffing box nut and gland. Fig. 1 has carbon steel body while Fig. 2 is made of stainless steel and is intended for use in localities where corrosive fumes are present in the atmosphere. Both patterns are made in 1/8, 1/4, 3/8 and 1/2 in. sizes.

A copy of booklet F-548 describing and illustrating these valves will be sent upon request.

Steam Turbine

To meet the need for a highly efficient and reliable steam turbine for sizes up to 60 hp., the Moore Steam Turbine Corp., Wellsville, N. Y., have placed on the market a new turbine, known as type U2RA.

This turbine has all the essential features found in the larger turbines, such as horizontally-split casing, carbon packing, emergency overspeed governor with independent trip valve, hardened tool-steel



governor wearing parts, babbitted bronze-backed split bearings, water-cooled

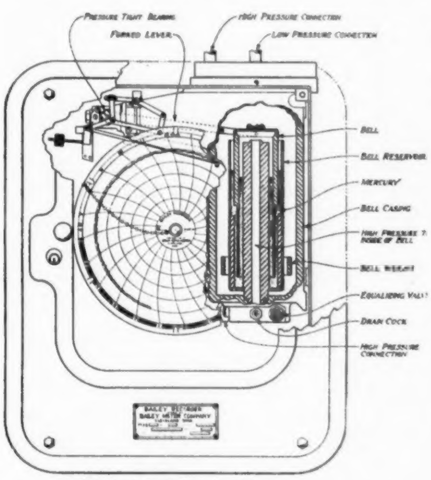
bearing cases, stainless steel governor valve and valve seats, heavy blading and stainless steel or nickel steel, and auxiliary nozzles for overload. Low steam consumption is secured by the use of a turbine wheel of ample diameter.

This turbine is of cast iron construction for moderate steam pressures and of all steel construction with centerline support for steam pressures up to 600 lb. and temperatures up to 800 deg. fahr.

Boiler Water Level Recorders

To meet the present trend of boiler design toward smaller water storage space, higher ratings, and higher pressures, the Bailey Meter Company, Cleveland, Ohio, has developed a complete line of Boiler Drum Water Level Recorders and Indicators. These devices give operators a complete picture of the rate of change of water level and show the true level throughout the full length of the drum, which is not possible with the gage glass. Records of water level are also of great value in preventing or determining the causes of boiler failures.

The Bailey Boiler Water Level Recorder illustrated operates on the difference in level obtained by making two connections to the water column or boiler drum; one connection being made to the water space, and the other to the steam space. In the latter connection a constant water head is maintained by means of a



Bailey Boiler Water Level Recorder

steam condensing radiator and a reservoir. The variable head or water space connection is applied over a mercury sealed bell and the constant head connection is applied to the inside of this bell. As the boiler water level rises or falls, the mercury sealed bell falls or rises and this motion is transmitted to the recording pen by a forked lever and a spindle which turns in pressure-tight bearings. A reversing linkage is employed between the spindle and recording pen so that the pen moves upward as the water in the boiler drum rises and moves downward as the water level drops.

A large variety of types and combinations are available in all pressure standards up to 1800 lb. per sq. in.

Vertical Enclosed-Design Transmission

The Reeves Vertical Enclosed-Design Transmission has been recently developed and placed on the market by Reeves Pulley Company, Columbus, Indiana. This new transmission unit incorporates the standard internal parts of the Reeves

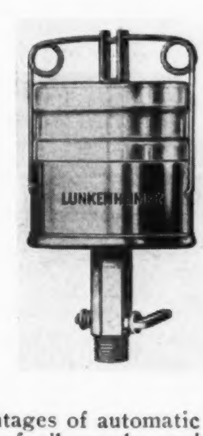
transmission and retains all the advantages of the horizontal enclosed design. The vertical design, however, is better adapted for certain standard equipment installations and where floor space is at a premium. The unit is completely encased in a dust-proof oil-tight cast iron case which provides complete protection against dust, abrasives, live steam, chemical fumes and other destructive elements.

An outstanding feature of the vertical transmission is the ease with which complete lubrication can be effected without the removal of the cover section. This is made possible by means of force-feed fittings located in two exterior panels and in each end of the shaft extensions. Another feature is the accessibility to the interior of the unit for inspection or adjustment by the removal of the side cover which is held in place by four cap screws.

The Reeves Vertical Enclosed-Design Transmission is available in ten sizes covering speed ratios ranging from 2 to 1 to 8 to 1.

Oil Cup

A new type of Wick Oil Cup is being marketed by The Lunkenheimer Company, Cincinnati, Ohio. It is called the "Glaswick" Oil Cup and provides



the advantages of automatic lubrication, visibility of oil supply, maintenance of constant oil level with consequent uniform feed, and ease in replenishing the oil supply.

The "Glaswick" Oil Cup has a capacity of approximately 4 ounces of oil. It consists of a steel cup with a shut-off cock in the shank, and a glass bottle which fits over the top of the cup. The bottle is held securely to the cup by means of a steel wire and clamp. Tight closure between glass bottle and steel cup excludes dirt.

When placed in service, the steel cup is filled with oil. The glass bottle is also filled and placed in an inverted position over the steel cup. Visible presence of oil in the glass bottle is assurance that the steel cup is full and the wick is absorbing sufficient oil to insure a constant uniform feed to the bearing.

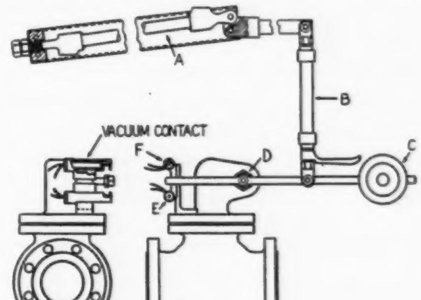
The cock in the shank permits shutting off the flow when the bearings are idle, making it unnecessary to remove the wicks to stop the feed. This shut-off feature also conserves the oil supply when machinery is not running. Further, it provides an accumulation of oil to flush the bearing when the cock is opened. After the accumulated oil runs out, the "Glaswick" feeds at the predetermined rate.

A copy of booklet F-532 containing complete information and list prices will be sent upon request.

Valve Signal Device

A new electric signal device has been developed by the Northern Equipment Co., Erie, Pa., for use with the control valve on the Copes Feed Water Regulator. It gives instant warning of any abnormal condition in the boiler feed supply by signaling by means of a bell or an electric light if the valve should ever reach the wide-open or fully-closed positions.

The application of this new unit is shown in the illustration. When expansion tube "A" of the Copes Thermostat



contracts with rising water level, the motion is transferred through the vertical strut connection and tension relief "B" to raise the weighted lever "C," gradually closing the valve. This lever pivots at the stuffing box "D" and the extended end moves downward. Should some abnormal condition cause the valve to reach a fully-closed position, the lever striking vacuum contact "E" closes the circuit for the "closed" signal.

As water level in the expansion tube lowers, the tube expands, permitting the weighted lever to open the valve gradually. Should the fully-open position be reached, the extended end of the lever strikes vacuum contact "F" and closes the circuit for the "open" signal.

The vacuum contacts are fully protected in a metallic case which is adjustable to any desired position. The signal may be installed on any Copes control valve.

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 491 boilers were placed in November according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658	603,401
June	1,360	1,588,553	818	677,434
July	1,309	1,410,096	816	687,058
August	1,371	1,356,751	827	594,698
September	1,254	1,282,388	893	692,238
October	1,189	851,525	672	467,375
November	777	709,322	491	424,044
Total (11 mo.)	12,352	12,882,840	7,608	6,835,301
December	814	587,053		
Total (Year)	13,166	13,469,893		

TOTALS FOR FIRST 11 MONTHS AND NEW ORDERS, BY KIND, PLACED IN NOVEMBER, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	Nov., 1931 No.	Nov., 1931 Sq. ft.
Stationary: Total	12,125	11,836,065	7,455	6,347,332	484	412,737
Water tube	1,038	5,432,439	635	2,649,155	42	142,933
Horizontal return tubular	856	1,151,113	465	588,748	21	26,119
Vertical fire tube	1,049	316,260	586	159,892	54	16,224
Locomotive, not railway	160	138,401	96	82,222	12	7,302
Steel heating	7,532	3,308,969	4,932	2,173,109	306	180,910
Oil country	948	1,081,204	389	439,740	23	24,895
Self contained portable	410	292,362	288	221,899	20	11,112
Miscellaneous	132	115,317	64	32,567	6	3,242

MECHANICAL STOKER SALES

November stoker sales, reported to the Bureau of the Census by the 21 leading manufacturers, totaled 62 stokers of 13,231 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929						
Total (First 11 mo.)	1,637	554,609	676	98,437	961	456,172
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
Total (11 mo.)	1,126	353,938	554	77,605	572	276,333
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
August	132	31,171	59	8,318	73	22,853
September	96	22,462	56	8,720	40	13,742
October	83	20,339	47	6,566	36	13,773
November	62	13,231	38	5,995	24	7,236
Total (11 mo.)	940	236,740	478	72,488	462	164,252

PULVERIZED FUEL EQUIPMENT SALES

November orders for coal pulverizers as reported to the Bureau of the Census aggregated 5 pulverizers having a total capacity of 17,850 lb.

Year and Month	STORAGE SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1931														
January	2	2	..	60,000	1	51,177	704,000	8	4	4	40,500	9	42,970	412,675
February	1	..	1	40,000	1	29,100	375,000	2	2	..	8,000	1	7,570	75,000
March	2	2	..	60,000	..	.....	......	13	13	..	122,000	8	93,960	1,404,000
April	2	2	..	60,000	1	34,300	592,000	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	......	..	..	..	......	..	.....	......
June	..	..	..	.....	..	.....	......	14	6	8	59,360	11	56,080	530,290
July	..	..	..	.....	..	.....	......	11	8	3	114,600	8	117,000	1,088,980
August	..	..	..	.....	..	.....	......	4	4	..	25,000	4	16,725	110,250
September	..	..	..	.....	..	.....	......	3	2	1	9,250	3	2,682	86,600
October	1	1	..	30,000	1	11,894	126,000	1	1	..	2,650	1	3,000	24,000
November	..	..	..	.....	..	.....	......	5	3	2	17,850	5	22,590	163,600
Total (11 mo.)	8	7	1	250,000	4	126,471	1,797,000	70	51	19	448,460	56	409,477	4,433,595
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1931														
January	..	..	..	.....	..	.....	......	6	..	6	6,000	6	7,500	53,350
February	..	..	..	.....	..	.....	......	3	..	3	2,250	3	3,000	22,350
March	..	..	..	.....	..	.....	......	2	1	1	2,750	1	3,004	22,500
April	..	..	..	.....	..	.....	......	1	..	1	4,000	2	6,700	45,000
May	..	..	..	.....	..	.....	......	3	1	2	3,800	3	6,000	27,000
June	..	..	..	.....	..	.....	......	4	1	3	4,000	4	5,750	22,100
July	..	..	..	.....	..	.....	......	5	3	2	3,900	5	8,000	47,700
August	..	..	..	.....	..	.....	......	4	1	3	4,250	4	7,307	43,600
September	..	..	..	.....	..	.....	......	4	4	..	4,350	5	5,000	22,500
October	..	..	..	.....	..	.....	......	2	..	2	3,500	3	6,000	34,000
November	..	..	..	.....	..	.....	......	..	..	..	.....	..	.....	......
Total (11 mo.)	..	..	..	.....	..	.....	......	34	11	23	38,800	36	58,261	340,100

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Boiler Feed Water Treatment

An interesting booklet entitled Hot Lime Soda Water Softening has just been published by the Permutit Company, manufacturers of water treating equipment. This booklet discusses boiler scale formation and the heat insulating properties of boiler scale. The three processes of water softening, namely the Zeolite, cold lime soda and hot lime soda processes are described. There are many illustrations and diagrams containing tabulated data, conversion factors, methods of calculating chemical charges, chemical reactions, etc. The various types of chemical feeding machines are shown and described. 24 pages, 8½ x 11—The Permutit Company, 440 Fourth Avenue, New York, N. Y.

Cinder Catcher

The Vortex Cinder Catcher is described in a recently issued catalog. Its construction and operation are explained and illustrated with drawings and photographs. This cinder catcher is of simple design, consisting of a steel casing enclosing the collecting elements and mounted over a hopper. The advantages claimed are high efficiency in the precipitation of fine ash as well as coarse cinders, flexibility of design permitting installation under difficult physical conditions, low draft loss, no maintenance and extremely low first cost. 8 pages, 8½ x 11, Dust Recovery, Inc., 15 Park Row, New York, N. Y.

Gas-Fired Air Heater

Bulletin No. 101 recently issued by Drying Systems, Inc. describes the Dry-Sys I-D-L Heater. This gas-fired air heater is the outcome of a period of intensive development work. The unit comprises generally, a heater element, a combustion chamber, gas burners and a fan. The heater is available in two distinct arrangements, namely the "Push-Through" and "Pull-Through." As the names imply, these designations refer to the location of the fan with respect to the heater. In the first arrangement, the supply fan discharges the air into and through the heater; in the second, it pulls the air through the heater. This heater ranges in capacity from 50,000 B.t.u.—100 cu. ft. air per min.—to 1,000,000 B.t.u.—3000 cu. ft. air per min. The field of application of this unit is to the drying, baking, annealing and other heat-treating processes. 8 pages, 8½ x 11—Drying Systems, Inc., Chicago, Ill.

Gas Flame Analyzer

A pamphlet entitled "The Application of the Brown Flame Analyzer in Coal Gas Plants," has just been issued by the Brown Instrument Company. This pamphlet describes the Brown Flame Analyzer equipment which shows to plant operators the exact condition of the gas made. This equipment gives a continuous record of the gas heating value and is entirely automatic and very simple in operation. The flame analyzer is also very useful in checking up air leaks in gas retorts and valves. A typical installation of the flame analyzer equipment in a coal gas plant is shown schematically. Two charts showing variations in gas quality when using a fish-tail burner as an operating guide and when the Brown Flame Analyzer is used are included. 10 pages and cover, 8½ x 11—The Brown Instrument Company, Philadelphia, Pennsylvania.

Gate Valves

Catalog No. 9000 describing the Hancock Gate Valve has recently been issued by Consolidated Ashcroft Hancock Company. The Hancock Gate Valve has a double disc which assures correct seating. Vertical grooves in the valve body guide the discs to their seats, and hold the discs away from the seats except at the time of actual seating. The thread bushing turns with the hand wheel, thus causing the stem to rise without turning. Lugs on the rising stem fit in the vertical grooves in the valve body and prevent any turning of the stem, eliminating the possibility of uneven pressures and the consequent strain being exerted on the discs. The seats and discs are made of MMM, a high nickel alloy. The bulletin includes illustrations of the various types of valves and tables showing list prices, dimensions and weights. 16 pages, 8½ x 11—Consolidated Ashcroft Hancock Company, Bridgeport, Connecticut.

Power Plant Instruments

A very comprehensive and interesting book entitled Republic Economy in Industry has been published by the Republic Flow Meters Company. The book is divided into two sections. The first section is devoted to the purpose and application of Republic Instruments together with typical installations. Some of the sub-heads in this section are Meters as an Aid; Instruments and Their Purpose; How Meters Eliminate Guesswork; Measuring Steam Distribution, etc. The application of these instruments to the various industries are discussed. Section Two is devoted to the theory of operation and construction of the Republic Instruments. Some of the sub-heads in this division are Reading Instruments; Reading Instrument Panels; Measuring Flow Electrically; Operation and Construction. Many charts, tables and sketches are included. 68 pages and cover, 8½ x 11—Republic Flow Meters Company, 2240 Diversey Parkway, Chicago, Illinois.

Semi-Portable Boiler Unit

The Erie City Iron Works have published a catalog describing the Erie City Economic Boiler. This boiler is a self-contained unit including the steam generator, furnace and brickwork. This unit is very compact and can be shipped directly from the factory completely assembled. When necessary this unit can be moved from one location to another as one of its advantages is its semi-portability. The Economic Boiler can be either hand, stoker, oil or gas fired. It is available in units ranging from 20 to 200 hp. and for pressures ranging from 100 to 150 lb. per sq. in. The catalog is very comprehensive, is well illustrated and printed. It includes a table of dimensions, cross-sections and setting plans. 24 pages, 8½ x 11—Erie City Iron Works, Erie, Pennsylvania.

Single Stage Turbine

The Moore Type U2RA Single Stage Turbine is described in a pamphlet recently issued by the Moore Steam Turbine Corporation. The Type U2RA Turbine has been developed to fill the need for an efficient and reliable steam turbine for capacities up to 60 hp. In this turbine have been embodied all the features which are necessary to insure continuous operation and which are generally found in larger turbines. 4 pages, 8½ x 11—Moore Steam Turbine Corporation, Wellsville, New York.

Small Electric Motors

Bulletin 167 recently published by the Wagner Electric Corporation describes the various small motors which it manufactures. The construction of the various parts of these small motors are gone into in great detail. Illustrations of the parts discussed are included. The bulletin also contains information relative to bearings and lubrication. 32 pages and cover, 8½ x 11—Wagner Electric Corporation, 6400 Plymouth Avenue, St. Louis, Missouri.

Welded Vessels

A pamphlet recently issued by the Blaw-Knox Company describes its new super-electric weld which has been given the trade name of Ductilweld. The pamphlet describes the results of a test conducted in which a Ductilwelded tank was submitted to a hydrostatic pressure of 10,000 lb. per sq. in. 4 pages, 8½ x 11 Blaw-Knox Company, 2090 Farmers Bank Building, Pittsburgh, Pennsylvania.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

BOOKS . FOR . THE . ENGINEER . .

1—Steam Generation Steps Ahead

By G. B. Gould

102 Pages Price $1.00

The major emphasis of this book is on the selection of the most suitable and economical coal for steam plants. The author's discussion of the factors of plant design and plant operation with respect to their influence on coal selection will be of very definite value to those concerned with this problem.

2—Heat Engines (Fourth Edition)

By John R. Allen and Joseph A. Bursley

540 Pages Price $4.00

An excellent textbook not only for the student engineer but also for the practical engineer who wishes to add to his technical appreciation of the equipment and operations under his charge. The various subjects are presented in such a manner as to permit a clear understanding of the principles involved, by readers of limited technical education. Many examples are given which enable the student to test his grasp of the material. The following subjects are treated: Heat; Elementary Thermodynamics; Properties of Steam; Calorimeters and Mechanical Mixtures; Fuels and Combustion; Boilers; Boiler Auxiliaries; Steam Engines; Testing of Steam Engines; Compound Engines; Valve Gears; Governors; Steam Turbines; Condensers; the Internal Combustion Engine; Fuels and Fuel Systems; Auxiliary Systems; Rating and Performance; Economy of Heat Engines.

3—A. S. T. M. Tentative Standards 1931

1008 pages Price: Cloth Cover $8.00
Paper Cover 7.00

This valuable book, published by the American Society for Testing Materials, contains the 180 tentative specifications, methods of test, definitions of terms and recommended practices in effect at the time of its publication. The specifications and methods of test represent the latest thought of the committee on the subject covered and are finding important applications in the various industries. This volume is complementary to and may frequently be used in conjunction with the A. S. T. M. Standards (Part I on Metals and Part II on Non-Metallic Materials) with its supplements. The items covered include ferrous and non-ferrous metals, cement, lime, gypsum, concrete and clay products and a great number of miscellaneous materials. The term "tentative" applied to a proposed standard published for one or more years, with a view of eliciting criticism, before it is formally adopted as standard by the Society. Should prove most convenient for reference purposes.

4—Pulverized Fuel

By W. F. Goodrich

215 pages Price $5.00

Contents: Pulverized Fuel—its origin and history; United States Practice; French and British Practice; Design, Equipment and Operation; Fuels Suitable for Use in Pulverized Form; The Future of Pulverized Fuel. Contains 88 illustrations, 16 tables.

5—Fortune's Favorites Portraits of Some American Corporations

(An anthology from *Fortune* Magazine)

350 pages Price $5.00

This book was reviewed in the January issue and has already received favorable comment. It presents, in an interesting, lively style, the history and present organization of America's leading companies covering, in a readable, clever and informative manner, the whole trend of American Industry, its trials, tribulations and successes. The reader gets an intimate picture of the inside workings of these organizations, and gets a "close-up" as it were of the men who run these companies. The companies included are: American Telephone & Telegraph Company, Swift and Company, Aluminum Company of America, Drug Incorporated, American Can Company, The Great Atlantic and Pacific Tea Company of America, International Telephone and Telegraph Corporation, R. J. Reynolds Tobacco Company, Allied Chemical and Dye Corporation, Standard Oil Company of New York, the New York Times Company, Bausch and Lomb Optical Company, Niagara Hudson Power Company, The Coco-Cola Company. The book is beautifully printed and bound in wine-color cloth.

6—The Problem of Fluctuating Loads on Boilers

By G. E. Hider

115 pages Price $3.00

The subtitle of this book is "An Investigation into the Characteristics of Different Types of Boilers, their Effect on Production Costs, and the Influence of Thermal Storage Systems." The book stresses the importance of *water content* as a factor in boiler efficiency, a matter frequently overlooked in other books on the subject. It is pointed out that under conditions of rapidly fluctuating load such as obtain in many industries, the quantity of steam delivered into the main is often far less than that corresponding to the feedwater entering the boiler and that the difference is a function of the water content of the boiler. This book should be of interest to engineers in large and small plants.

Postage prepaid in the United States on all orders accompanied by remittance or amounting to five dollars or over.

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